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ABSTRACT

Reported is a variety of studies associated with the development of new elementary science programs in the Boulder Valley School District. Three approaches to elementary science were given field trials, one using textbooks based on a conceptual schemes approach, one based on the Elementary Science Study materials, and the other based on the American Association for the Advancement of Science "Science - A Process Approach." Tests were developed to measure changes in childrens' critical and creative thinking, and a classroom observation system was developed to categorize teaching styles as expository, inductive, or indeterminate. In a later phase of the project, teachers were given a choice of a textbook-based or non-textbook course. Data are reported bearing on the effects of curriculum materials, teaching styles, type of course chosen by the teachers, and on changes in student critical and creative thinking abilities. Both the expository and inductive teaching styles proved superior to the indeterminate style in producing changes in creative thinking; the non-textbook course favored creative thinking. Also reported is a study of the effect of different instructional methods for developing the concept of conservation at the first grade level. Appended are a report of the development of a group measure to assess pre-causal and pre-logical thinking in primary school age children, and copies of the tests of critical thinking and creative thinking. (EB)

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FINAL REPORT

Pace Project No. 1312

Grant No. OEG 4-6-001312-0767(056)

BOULDER ELEMENTARY SCIENCE PROJECT

Developing Creative and Critical Thinking Through an Elementary Science Program

August, 1969

Boulder Valley School District Re2
Boulder, Colorado

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Developing Creative and Critical Thinking Through an Elementary Science Program

PACE PROJECT 1312

Contract No. OEG 4-6-001312-0767(056)

Joseph A. Struthers

Project Director

August, 1969

The research reported herein was performed pursuant to a contract with the Office of Education, U.S. Department of Health, Education, and Welfare, and with the Colorado State Department of Education. Contractors undertaking such Projects under governmental sponsorship are encouraged to express freely their professional judgment in the conduct of the project. Points of view or opinions do not, therefore, necessarily represent official positions or policies of either the U.S. Office of Education or the Colorado State Department of Education.

Boulder Valley School District Re2

Boulder, Colorado

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Development of a Group Measure to Assess the Extent of Pre-logical and Pre-causal Thinking in Primary School-Age Children

Thinking in Science, Form I of the Boulder Test of Critical and Creative Thinking

Preface

The program described in this report has been functioning for a little over three years in the interface between educational practice and educational research. A particular assumption of the project was that there is a gap between what is known about the nature and development of children's thinking and how much of this information is translated into instructional practices and that this gap needs to be closed. A second assumption was that there exists also a wide gap between the quality of science instruction that exists typically and the quality obtainable as demonstrated by those teachers and scientists whose collaboration has produced new programs of instruction for elementary science.

It has been our belief that these two areas of concern were sufficiently related to justify their inclusion in a single effort.

Certain hazards obtain from the adoption of a practice-research interface frame of reference. Even the most substantial appearing findings must be considered exploratory and descriptive for any field investigations in classroom settings contain more variables than can be contemplated much less controlled. Many of the conditions on which rests the validity of statistical tests could sometimes be met only marginally. The researcher will doubtless point out the need for vastly delimited objectives, operationalized definitions and better documented procedures. The practitioner on the other hand may well tire of introspection, questioning and the expression of doubt to the point of indecisiveness.

The project has followed an adaptive path toward admittedly optimistic objectives through the process of making decisions based on what data could be obtained but tempered by subjective judgment with the realization that only a small portion of relevant factors could be reduced to numerical data.

Many ancillary undertakings occurred in conjunction with the central thrust of the project. An initial question which was studied was that of determining the boundary conditions for curriculum change in elementary science. The design and development of measuring instruments was a frequently reoccurring task.

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Acknowledgments

The Boulder Elementary Science Project owes its existence to the cumulative contributions of literally hundreds of adults and thousands of children and giving individual credit to each is not possible. Nevertheless, the project would not have begun nor continued without the support and hard work of the following people.

It is only in an environment receptive to innovation, experimentation and change could such a project function. Such an environment has been established and maintained by Superintendent of Schools, Dr. Paul E. Smith, and his predecessors, Dr. Richard M. Fawley and Dr. E. G. Burnkrant. The original idea for the project was Dr. Fawley's and he authored the first proposal. Consistent in their support of the day to day operations of the project have been Assistant Superintendent for Elementary Education, Melvin L. Wiesley; Assistant Superintendent for Supporting Services, Eugene R. Gullette; and Science Supervisor, Ralph E. Bachus.

Financial support of the project has been in the form of a grant from the U. S. Office of Education under the provisions of Title III of the Elementary and Secondary Education Act of 1965. Dr. Robert Mulligan and Dr. Lee Wickline, representing the U. S. Office of Education, and Dr. Lewis Crum, Dr. Christian Pipho and Dr. Walter Turner, representing the Colorado State Department of Education, have assisted greatly in matters pertaining to the operation of the grant.

Key people in the project are the teachers who translated ideas and suggestions about teaching science into meaningful classroom events. Regretably most of this work goes unnoted by anyone except for the children involved. There were individual teachers who, in addition to doing an artful job with their own classes, also found time to assist other teachers, to write, and to perform a leadership role in general. The following teachers served in such a capacity for two or more of the years of the project:

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CHAPTER I - OVERVIEW

Context

The Boulder Elementary Science Project had its beginning in a local school district in a pilot program investigation of several elementary science study units by a group of 40 teachers. This pilot program began in the fall of 1965 and proceeded throughout the year. Growing out of this initial experience were the beliefs that

1. Elementary science can be an appropriate vehicle to foster creative and critical thinking in children; in particular, activities which involve the children in an inquiry or discovery approach which would lend themselves to this goal.

2. In order to overcome the barriers to implementation related to teachers' attitudes, lack of involvement and insecurity in dealing with new content, a change in strategy which would involve teachers as co-researchers in the project, was needed.

3. A broad scale change affecting most classes in the district needed to be accomplished.

As a consequence of this pilot program, a proposal was written to be submitted under the provision of Title III of the Elementary and Secondary Education Act of 1965. The purpose of the project described in this initial proposal were to

1. Plan and operate an exemplary science program in the elementary school levels which would help students to acquire the skills of critical and creative thinking.

2. Increase elementary school teachers' understanding of creative thinking by involving them as co-researchers in this project.

3. Acquire the instructional strategies used by teachers which successfully elicit creative and critical thinking.

The area served by this project is called the Boulder Valley School District Re2 which comprises an area of 400 square miles in the southern half of Boulder County, Colorado. The area's main population center is the city of Boulder, with a population of approximately 60,000 surrounded by several smaller towns and a substantial suburban population. Public schools in the Boulder Valley School District enroll approximately 20,000 students. Also included in the project are private and parochial schools enrolling approximately 1,000 students. A characteristic of the school district which is relevant to the need for an appropriate school science program is the scientific base of the community, including the University of Colorado, major governmental science facilities, including the National Center for Atmospheric Research, the Bureau of Standards, and a substantial scientifically oriented industry. At the same time the community does include a wide range of social and economic variables, with some students defined as educationally disadvantaged for economic reasons.

The per pupil expenditure of the school district is high relative to other 12 largest school districts in the state ($675. for the 1967-68 school year) and the pupil teacher ratio is low (19.1 for 1967-68). The district experienced a growth rate which exceeded the level of construction of new classroom space with the result that during the years of the project's operation, the enrollment exceeded the classroom space by as much as 2,000 students, resulting in the use of rented space not initially designed as school classrooms. This description should serve to suggest that the project operated in an environment which was unusual in certain respects but which also shared many of the problems typical of school districts serving minor urban and suburban populations across the country.

Phase I

With the approval of the project, a brief planning period was begun in May of 1966. A review of contemporary writing regarding elementary science discloses that there are substantial differences in belief among those responsible for curriculum development. These differences are expressed in the kind of materials developed to accomplish elementary science educational objectives. Among the many shades of point of view, three were identified by project personnel as being representative.

One belief is that skills in the processes of science which children develop are the most important outcome of the science program.

It is assumed that skills such as measuring, observing, describing, inferring, interpreting data, and others, must be developed before the individual can become a mature, independent scientific inquirer. With such an assumption, elements of content and the nature of the instructional sessions can then be selected so that appropriate skill development will be more likely to occur. The most comprehensive materials which are designed from the process skills point of view are those by the AAAS Commission on Science Education called Science, A Process Approach.

Another viewpoint is gained by looking to the conceptual structure of science for a way of organizing science instruction. There are large conceptual schemes within the body of science which remain quite stable over long periods of time as contrasted with facts which are subject to more frequent modification or change. The efforts of a curriculum committee of the National Science Teachers Association provided a substantial list of conceptual schemes which can serve as an organizing structure for the curriculum. A next logical step is to break major conceptual schemes into supporting concepts, arrange these in order of difficulty and emerge with a science curriculum which is structured to imbue students with the central ideas in science. Such a reference frame has resulted in several textbook series which provide a logical and sequential development of the central body of scientific knowledge.

Yet, a third point of view is that each student must build his own organizing principles and structure the world of science for himself. Logical structures superimposed on the student's thinking are considered not likely to cause more than superficial changes unless actively assimilated by the student. The strategy for insuring a high level of student involvement consists of providing an environment replete with discoveries to be made and phenomenon to be investigated. The choice of content elements depends upon how interesting the material is to students and whether or not it is appropriate for the student's own investigation. Material produced by the Elementary Science Study of Educational Development Corporation is representative of this third point of view.

With these options available and with each having a substantial group of highly competent advocates, it seemed imperative that development of an exemplary elementary science program be broadened to include more than one point of view and that a field trial implementation of the alternatives be undertaken. The planning phase concluded with the establishment of a comparison between a process approach to elementary science, a concepts approach to elementary science and a discovery approach to elementary science. Each of these programs was established in a comparable setting involving six teachers at each grade level. Contemporaneously with this design was the development of programs of inservice education to equip teachers to deal effectively with the three programs. These programs of inservice education included as resource teachers with experience in the pilot program and consultants from outside the district who had a degree of expertise with the new science materials. This three-program comparison was conducted on a school unit basis with principals agreeing to undertake a particular program as assigned by chance and the teacher assigned to those schools asked to participate. Anticipated outcomes were several. One outcome was the determination of what effect, if any, science curriculum change would have on childrens' critical and creative thinking. Also, boundary conditions for curriculum change in terms of program acceptance and feasibility were matters to be determined. The teachers who had initially participated in the pilot program were continued in that program with a considerable expansion of the number of units in use.

Additonal planning and developmental work went into the implementation necessary for the measurement of creative and critical thinking and into the development of a model of classroom interaction.

Phase II

Principle findings of this first year investigation were complex. First, none of the curriculum designs--process, concepts or discovery--were universally acceptable to teachers. Each program had its supporters and detractors. Extensive comment was obtained by participating teachers and specific differences between the programs in terms of the reaction of the teachers was analyzed. Many of the difficulties were centered in the quality, timeliness and appropriateness of materials acquisition. However, another important part of the teachers' responses--both negative and positive--turned on such issues as philosophy, teaching style, class management skills and other fundamental issues. Responses from parents indicated that either of the two non-text programs--process and discovery--was more acceptable to parents than the text-based concepts approach. The changes in creative and critical thinking as measured by the testing program were not attributable to curriculum. The changes were attributable, however, to the influence of individual teachers with some classes showing gains and other classes showing losses, particularly in the area of creative thinking. This collection of data did not support a simple decision, i.e., to adopt one program in favor of the other two. In fact, the intensity of responses suggested that such a simple decision was not tenable. There were modifications for which a clear need was indicated. These changes pertained to supply and equipment acquisition and the strengthening of certain weak points in the non-text programs. Two considerations emerged from the three-program comparative study. One was consideration of the premise that an exemplary elementary science program should accommodate substantial teacher variability to the extent that perhaps a selection of alternatives would prove more beneficial to everyone than any unitary choice. The second consideration was that although based in opposing schools of philosophical and psychological thinking, in practice, the two non-text programs proved more alike than different, particularly when compared to the text program. This observation coupled with the weak spots encountered in non-text programs, led to an attempt to merge process and discovery science teaching approaches into a single non-text sequence. This sequence had the major emphasis of the process approach in the primary grades with some components from the discovery approach and major emphasis on the discovery approach in the intermediate grades but with some contributions from the process approach.

Phase III

A question emerging from the observations of changes in creative thinking encountered during the second phase was could the teacher attributes which influence creative thinking be identified? This question was posed in the form of a study to relate changes in creative and critical thinking to classroom teaching behavior. An expository-inductive teaching style mode was proposed and a rating scheme evolved by which videotape recording of class activities could be analyzed. A sample of teachers were selected and classes pretested in the fall of 1967 and again tested in May of 1968.

In the intervening months videotapes of science instruction were made and analyzed. The conclusion from this study was focused on three instructional types: Teachers who use a predominantly expository style, teachers who use a predominantly inductive style and teachers whose style defied classification in the expository-inductive continuum. The influence of teaching style on critical thinking as measured by the tests developed proved to be minimal. Creative thinking, however, was influenced favorably by teachers with either a predominantly expository style or by teachers with a predominantly inductive style as contrasted with the losses in creative thinking associated with teachers of indeterminate teaching style.

In the spring of 1968 as these results were becoming known, decision was made to provide a text or non-text alternative and extend to teachers the option to elect one or the other alternative for the 1968-69 school year. Such a choice was extended to all the teachers with an elementary science teaching responsibility and approximately one-half of the more than 400 teachers elected the text alternative while the remainder elected the non-text alternative. During the summer of 1968, materials to implement these choices were obtained and distributed and inservice education activities were designed to assist teachers in strengthening their work with the materials of their choice.

Phase IV

The teaching style study was conducted in classrooms outside the original three-treatment design and as a result of teachers exercising their option to change to the program of their choice, the schools in the initial three-treatment study had approximately half of their staff utilizing the text and non-text alternatives. This provided a means of investigating the relationship between critical and creative thinking and classes in which teachers were using science materials of their own choosing. Children from these initial schools were again tested with instruments designed to measure creative and critical thinking and also science achievement. Data from this testing program again suggested that changes in critical thinking are minimally affected in this case a combination of teacher and program, but that creative thinking scores are higher in classes where non-text materials are being used by teachers than scores in classes where the text materials are the selection of the teacher Achievement as measured by the STEP science battery is high in both groups as compared to published norms and favor slightly the non-text classes but not significantly so. The practice of extending the opportunity to choose programs has been continued and in the selection of materials in the 1969-70 school year follows approximately the same pattern as the 1968-69 school year except that there is a small increase in the percentage of teachers selecting the text approach.

A limited study of the effectiveness and efficiency of different instructional styles suggested that with first grade age children, an instructional strategy through which the child receives feedback directly from the environment in the form of a balance scale is superior in effectiveness and equal in efficiency when compared to instructional strategies which utilized either teacher or peer interpreted data.

The text and non-text alternatives are being continued as a part of the regular instructional program past the termination of federal funding. A program of new teacher inservice education, and provision for continued adaptive change of the programs, has been established. Other work to investigate problems which have arisen as a result of this project are under study.

Subsequent chapters of this report present the description and findings of the project in more complete detail.

CHAPTER II - A FIELD TRIAL OF THREE KINDS OF ELEMENTARY SCIENCE

A. Introduction

The work of curriculum development groups has served to increase the variety of science programs available to schools. These programs show the mark of talented scientists and teachers and come with the endorsement of qualified authorities and present a difficult choice for schools.

No matter how well conceived, a program of instruction is only as good as it is implemented in terms of daily interactions among teacher, children and materials.

Having undertaken the task of establishing an exemplary elementary science project, the decision was made to base selection of materials on as empirical basis as possible. A field trial of materials was designed to test the feasibility of materials and their effectiveness in improvind children's thinking. The critical and creative thinking outcomes were selected because of their importance and because they would not obtain more directly from one approach than from another as would be the case if process skills or conceptual information or inquiry skills were evaluative criteria.

The cirricula included in the trial and the nature of the treatment are described under the following headings of Concepts, Discovery, and Process.

Concepts - Students study science in the order and manner suggested in the 1966 Harcourt, Brace and World science series, Concepts in Science. Such Study includes the reading of narrative and descriptive material in the text; such laboratory investigations as are suggested in the text and deemed appropriate by the teacher. The Harcourt, Brace and World kits of materials are made available to the classes and used in the manner prescribed. Teaching tests are utilized in grades 3 through 6. The structure of instructional sessions and the sequence of topics is relatively strong and determined by the teaching guides. This treatment is considered as a textbook-centered approach.

Discovery - Students study science in the order and manner suggested by the Boulder Public Schools' Science Guide. This is predominantly units produced by the Elementary Science Study of Educational development Corporation (formerly ESI), augmented by additional units developed locally to provide for a year's study in science at each grade level.

The units are introduced by giving students direct experience with a problem-provoking situation.

Materials are provided for individual student manipulation and consist principally of kits of materials developed by the Elementary Science Study, commercial versions obtained from the Webster Division of the McGraw Hill Publishing Company. This treatment is considered a relatively unstructured inquiry approach.

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Process - Students study science in the order and manner suggested in the AAAS-Science, A Process Approach materials, parts 1-7. The appropriate kits of materials are obtained from the Ideal School Supply Company and Macalester Scientific Company. Instructional sessions and the sequence of topics are largely controlled by the material presented in teaching guides. This treatment is considered to be a process-centered approach and is relatively strongly structured along process skill developmental lines.

The district elementary schools were studied in order to find satisfactory populations for comparison purposes. The scope of the project which was feasible allowed for the inclusion of six teachers per grade per treatment. Schools which had a large number of pilot program teachers from the previous year or which were atypical for some reason were not selected. All teachers in selected schools were asked to participate and all agreed.

The following table summarizes the design:

		Treatment	
Type School	Concepts in Science, HBW series	Predisciplinary Inquiry, ESS units, augmented locally	AAAS series, Science, A Process Approach
New neighborhood schools. 4 teachers/grade	29 teachers 832 students	23 teachers 718 students	27 teachers 734 students
Established neighborhood schools 2 teachers/grade	16 teachers 373 students	14 teachers 335 teachers	14 teachers 406 students
Totals	45 teachers 1,025 students	37 teachers 1,053 students	41 teachers 1,140 students

An additional 5 teachers per grade who were not involved in the project were identified and their students tested for control purposes.

Outside the experimental design, another 100 teachers participated in a program designated as "eclectic". While most of their material was identical to the Discovery materials (ESS), there were also elements of the other two treatments included. Forty-three of these teachers were pilot program teachers of the previous year, the other fifty-two were first year teachers and twelve of these were parochial school particpants.

All 223 teachers, both within and outside the experimental design, participated in a series of inservice education sessions designed to assist them in implementing a particular program at the appropriate grade level. The typical project teacher attended three half-day inservice sessions and three after-school meetings for a total of about fourteen hours of inservice activity.

Measurement Instruments

Creative Thinking - The Torrance Tests of Creative Thinking were chosen as the best available measures of creative thinking. The figural test was used for grades 1, 2, 3, 5 and the verbal form for grades 4 and 6. The tests were administered to a randomly selected sample of children consisting of six per class in September and May. Forms A and B were alternated as pre and post tests.

Critical Thinking - In the absence of appropriate measures available from other sources, two instruments were developed to measure critical thinking. One called the "Boulder Picture Test" was designed for use with children in grades 1, 2 and 3. The other called "Critical Thinking in Science" was developed for grades 4, 5 and 6. Pretest information was obtained in October for the Picture Test; however, time limitations precluded pretesting with the Critical Thinking for grades 4, 5 and 6.

In order to determine the direction for future development, information was collected from three principle sources. First, the opinion and evaluation of participating teachers was gathered by means of a questionnaire form supplied at the end of the school year. Second, information was obtained from a sample of parents whose children were in participating classes. Finally, tests of critical and creative thinking were given to a randomly selected sample of children in the three science programs.

B. Summary of Teaching Experiences

Questionnaire forms were completed and returned by participating teachers. The evaluation team read and tabulated the returned questionnaires and members of the team summarized the responses into this narrative form.

The replies were sorted into five groups representing somewhat common experiences. Participation in groups 1, 2 and 3 was established by schools--all of the teachers in a particular school participating. Teachers in these groups were representative of the school district as a whole and it is reasonable to expect that the same degree of success or failure can be expected with the several programs if tried on a district-wide basis.

Group 1 used the program made up of Elementary Science Study units augmented by locally developed units. This program has come to be known as the "Discovery" approach. Group 2 used the program used the AAAS Commission on Science Education known as the "Process" approach. Group 3 used the Harcourt, Brace & World science series and has been called the "Conceptual Schemes" approach or "Concepts" approach. Groups 4 and 5 used the same program as group 1 but are considered separately since the participants might not be typical of the school district as a whole for one reason or another. Group 4 consists of volunteers who actively sought out participation in the project. They are scattered among most of the elementary schools in the district. This group also includes teachers from the parochial schools. Group 5 includes those teachers who were in the original pilot program and who are completing their second year of participation.

Interesting differences of opinion developed among the five groups.

1. Group 1 - Discovery Appraach

Responses were received from the 34 of the 37 teachers in this group. These responses were sorted into three categories--favorable, unfavorable or neutral--on the basis of whether the overall evaluative statements were favorable towards the program, unfavorable towards the program or whether an equal number of favorable and unfavorable comments were made. There were 16 in the favorable group, 7 neutral responses and 11 responses which were clearly unfavorable.

Comments made on the questionnaires classed as favorable included mention of high student interest and opportunity for individual participation. Most favorable responses came from kindergarten, fifth and sixth grade teachers Even among favorable responses there was concern expressed for lack of quantity or poor timing of materials, not enough inservice activity and there was some scattered criticism pertaining to lack of organization.

The neutral group commented extensively, pointed out the need for more materials, that the program needs to be augmented and extended, expressed disapproval of the quality of the inservice and the lack of structure.

The unfavorable group was very strong in criticism of the program. The criticisms were strongly stated and the participants took the time to write long comments. The material supply was the problem most strongly stressed but, in addition, the equipment was criticized on the grounds that it is unsuitable or dangerous for use in the classroom. The inservice activities were called waste of time and poorly organized. The organization of the materials for teachers were criticized, not enough information of a content sort provided for teachers, and there were several suggestions that textbooks were needed.

In summary, the logistic problem of supplying sufficient materials for individual student use and at the proper time was identified as a principal program shortcoming. This difficulty hindered some teachers and overwhelmed others. The other severe shortcoming identified by these teachers was the lack of structure, direction or organization. The suggestion that children can learn worthwhile things through their own discoveries was frequently rejected outright as indicated by those who used few or no units on the grounds that "the program is not suitable to classroom size and problem" or "I can't see letting a student go on his own--they need direction and guidelines." 'This is great philosophy but it doesn't work to just let them go." Particularly unfavorable responses were received from teachers of first and fourth grades.

2. Group 2 - Process Approach

Thirty-seven responses were received from the 40 participants using the "Process" approach materials. Of these 24 responded favorably, 10 neutral and 3 wrote negative responses. The favorable responses were frequently enthusiastic, indicating the belief that the program was more effective than the previous type of program and that the students became more involved and more interested in science. There were concerns expressed about the teacher's adequacy and suggestions that more inservice was needed were frequent, particularly in the upper grades. These comments generally had a positive tone with the expression that the teacher expects to do a much better job next year.

The neutral group considered preparation time required to be excessive, the teacher guide too technical, arrival of materials tardy. The neutral group also suggested that storage of the materials was a problem, specialists were needed and that the material was too hard for the children.

The unfavorable comments most frequently came from first and fourth grade teachers and suggested that the program is too hard, the children not ready and the teacher preparation time too great. Some suggested that the program included too much discussion material and that the interest of the children were not stimulated. Two simply stated it was disappointing.

In summary, this program seems to have been well received by the majority of teachers, the notable exception being first grade, but the overall tone was positive with criticisms accompanied by suggestions as to how the problem can be overcome in the future. The equipment did not always arrive in time, however, its quantity and appropriateness seemed satisfactory. There was a certain amount of concern expressed about the time consumed in getting the necessary living organisms or consumable supplies needed for the activities. The most promising response was the very general belief that the program had favorable effects on the children.

3. Group 3 - Concepts Approach

Thirty-six teachers out of 41 responded, 24 responded favorably, 9 with neutral comments and 3 responded unfavorably. Teachers responding favorably indicated that they had enough materials to use for a change. Some thought there was too much material to cover comfortably. There were occasional apologies for not having covered the entire text. The favorable group generally expressed satisfaction about having materials, curriculum and texts.

The neutral group made relatively few comments but did include suggestions that units didn't allow enough time "to materialize", that "deviation from the text was necessary to clear up questions which came up." Some parts of the text were called too easy, others too hard. One teacher suggested that the guide was too didactic and that following the sections suggested produced less interest in science. Another thought the concepts too large and broad.

Participants responding unfavorably suggested that they wanted fewer units and more time spent on each one, that there was too much reading, that children did not do enough of their own experiments and the children did not become involved. They also indicated that there was too much material if the guide was followed too closely.

In summary, participants in this program seemed generally satisfied or pleased with the concepts approach although a few felt constrained by it. The comments were generally mild in nature, favorable comments as well as unfavorable comments. This program seemed to fit the teachers' expectations.

4. Group 4 - Discovery Approach, Volunteer Teachers

Forty-nine out of 66 teachers in this group responded. Twenty-nine responded favorably, 17 neutral and 3 responded unfavorably. The favorable group suggested that the program caused children to think and develop answers to questions, some suggested that the bigger variety of units would be desirable. Many reported there is much interest and enthusiasm among the children. The favorable group also indicated materials were too late in arriving, some felt materials were too few in quantity. More workshops were requested. Other favorable comments were that it is "lively science", "kids have learned to ask questions about things" and "it is fascinating for the children."

The neutral group commented that the teacher materials were sometimes hard to follow, more units with more materials were needed, planning of the meetings could be improved, timing of the materials should be improved.

The unfavorable group had similar comments about the materials problem but centered comments on the lack of structure existing in the program. They feel that the class was harder to control and that the children lost interest after an initial interest, and finally, that more content was needed in order to prepare for junior high school.

In summary, this group was about evenly divided between participants giving favorable responses and neutral responses. The favorable responses were enthusiastic; large differences between reception at different grade levels did not appear.

5. Group 5 - 1965-66 Pilot Program Teachers

Twenty-nine responses were received from 35 teachers finishing their second year. Fifteen responses were considered favorable, 10 neutral and 4 considered unfavorable. Virtually all of these participants had provided favorable responses at the end of their first year's experience.

The participants responding favorably indicated that the program is of great potential in terms of its favorable effects on children. The potential was only partially reached because of supply problems and insufficient inservice opportunities. Some concern was expressed about means for evaluation and whether or not the children were going to be prepared for junior high.

The neutral group suggested that there was a lack of supervision, inservice or involvement as well as materials problems.

The four unfavorable responses included excessive time requirements, lack of structure in the units and lack of tangible results as barriers. One suggested that a "whole year of this kind of work gets boring"; another said "discovery is a good technique but it can not be used to the exclusion of other techniques."

In summary, the experienced teachers seemed to suffer a letdown in enthusiasm from their previous year's experience. More opinions were favorable than otherwise but there was evidence of a feeling of disaffiliation with the program objectives. Concerns for evaluation, preparation for junior high, and a balance between teaching techniques appeared. Three asked for a "good text".

6. Global Comparisons

In order to obtain general impressions about the degree of acceptance of the three programs, members of the evaluation team read the responses for a single grade level, rating the overall response by grade as unfavorable, neutral, favorable and very favorable (-, 0, +, ++). These grade level ratings were then summarized and members of the evaluation team made comparisons between the different groups. There was general agreement among judges about the relative position of the different groups.

For the situations in which all teachers in a given school participated, Group 2 - Process Approach rated highest followed closely by Group 3 - Concepts Approach. Group 1 or the Discovery Approach was rated as least favorably received. The differences between Group 3 and Group 1 were greater than between Group 3 and Group 2.

(Favorable . 2 . . 3 . . . . . 1 . . . . Unfavorable).

For the three groups using the Discovery Approach materials, the order was Group 4 - New teachers participating by request--responding most favorably; Group 5 - Second year participants next, and Group 1, again responding least favorably. Groups 4 and 5 were again closer in response than Groups 5 and 1. (Favorable . 4 . . 5 . . . . 1 . . . . . . Unfavorable).

C. Responses of Parents

A questionnaire was sent to parents of children in the three experimenta trials to establish if there were differences in the children participating in the science programs which were observed by parents. These three trials correspond to teacher groups 1, 2 and 3 in the previous discussion. Parents were selected randomly from student lists, and contacted by telephone to determine if they would complete the questionnaire. The first response and one followup request produced better than a 90% return.

The first question was "Were you aware prior to this letter that your child's class was taking part in a new science program this year?" Responses indicated that virtually 100% of the parents of children in the Discovery Approach were aware that the children were participating in a new program. Approximately one-half were initially informed by the children and one-half by the teacher. Eighty percent of the parents completing the questionnaire in both the Process Approach and Concepts Approach were aware that their children were participating in a new program and the children and teacher also constitute the main sources of information.

The second question was "Have you observed a change during the year in your child's interest in school-related science activities?" (i.e., bringing home projects initiated at school for additional study.)

The table shows the responses of parents whose children were in the three different science programs.

	Discovery	Process	Concepts
More Interest	54%	48%	22.5%
No Change	42%	50%	70%
Less Interest	4%	2%	7.5%

TABLE I - Interest in School Related Science Activities

The third question was "Have you observed a change during the year in your child's participating in science related activities outside the school program?" (i.e., choice of reading, projects, questions). Responses of parents of children in the three science programs are shown in Table II.

	Discovery	Process	Concepts
More Interest	53%	44%	21%
No Change	47%	56%	79%
Less Interest	-	-	-

TABLE II - Interest in Outside Science Activities

The fourth question was "Have you formed an opinion about the merit or effectiveness of the new science program? Table III shows the responses of the parents.

	Discovery	Process	Concepts
Favorable Opinion	48%	46%	11%
No Opinion	52%	54%	84%
Unfavorable Opinion	-	-	5%

TABLE III - Parent Opinion about Science Program

From this information it seems that the impact of the Discovery and Process Approach on parents was approximately equal. Parents whose children were in the Discovery Approach reported slightly more favorable change in their child's interest in school and outside school science activities, while many more parents were asked about their opinion with nearly one-half of the parents in the Discovery Approach and Process Approach reporting favorable opinion while the majority of the parents of the children in the Concepts Approach had formed no opinion.

D. Test Results

1. Creative Thinking

A sample of 6 children-- 3 boys and 3 girls--was selected, using a table of random numbers from each class in the Concepts, Process, and Discovery programs. In addition six children were selected from six other classes in the district where none of the science programs were being used. This latter group was designated as a "Control." The "Torrance Tests of Creative Thinking" were administered to these children during September and again in May. Half of the children in each program received Form A followed by Form B; the other half received Form B followed by Form A. The figural test was given to children in grades 1, 2, 3 and 5. The verbal form was given to children in grades 4 and 6. The figural test has four separate scales--Fluency, Flexibility, Originality and Elaboration. The verbal form has three scales--Fluency, Flexibility, and Originality. A brief definition of these scales is as follows.

Fluency - The number of relevant responses produced.

Flexibility - The number of shifts in thinking or number of different categories of questions, causes, themes or representations.

Originality - The statistical infrequency of these questions, causes, themes or representations or the extent to which a response represents a departure from the obvious or commonplace.

Elaboration - The detail and specificity incorporated into questions, causes, themes or representations.

The following table of significance levels for changes in the creativity scales was obtained from a one-way analysis of variance. (N=653, ns=not significant).

Grade	Scale			
	Fluency	Flexibility	Originality	Elaboration
1	n.s.	n.s.	n.s.	n.s.
2	n.s.	n.s.	n.s.	n.s.
3	n.s.	n.s.	n.s.	n.s.
4	97.5	n.s.	n.s.	---
5	90	n.s.	90	n.s.
6	97.5	90	n.s.	---

TABLE IV - Differences Among Treatments

Inspection of Table IV suggests that no important changes are attributable to science curriculum treatment.

When the analysis is repeated with class membership (teacher influence) as the variable of interest the following table is produced.

Grade	Scale			
	Fluency	Flexibility	Originality	Elaboration
1	99.95	99.95	99.95	99.95
2	99.95	n.s.	95	99.95
3	90	99.95	99.95	99.95
4	99.5	99.9	99.5	---
5	90	99	90	99.9
6	97.5	n.s.	99	---

TABLE V - Differences Among Teachers I

A further analysis by means of a one way multivariate analysis of variance (profile analysis) collapsed the data for four scales and produced the following composite for teacher influence.

Grade	Significance Level
1	99.95
2	99.95
3	99.95
4	99.95
5	99.5
6	99.95

TABLE VI - Differences Among Teachers II

The interpretation of these results is facilitated by considering the following example which shows the first two class results printed out in the analysis of variance for teacher influence.

	Fluency	Flexibility	Originality	Elaboration
Teacher 1	-16.4 (loss)	-1.4 (loss)	-2.0 (loss)	-12.4 (loss)
Teacher 2	+18.0 (gain)	+6.8 (gain)	+32.2 (gain)	+24.0 (gain)

TABLE VII - Average Change in Raw Score Units in Two First Grade Classes.
(Pretest: October, 1966, Posttest: May, 1967)

Teachers 1 and 2 were using the same science curriculum materials, in the same school and in adjacent rooms, but they clearly did not produce the same effect on children's creative thinking.

2. Critical Thinking, Grades 1, 2, 3

During the year a cartoon format test called the Boulder Picture Test of Pre-critical Thinking was developed. This test contained items in three scales measuring Conservation of Substance, Spatial Relations and Logic. Table VIII shows the mean raw scores for grades 1, 2 and 3 taken together. Approximately 100 children were in each sample. A description of the Boulder Picture Test is included in the Appendix

	Discovery	Process	Concepts	Control
Conservation	5.56	5.29	5.32	5.32
Relations	3.70*	3.37	3.24	3.20
Logic	4.46	4.25	4.27	4.34

TABLE VIII

*Discovery mean > concepts or control means at .05 level of significance.

The table shows that mean scores of children in the Discovery program tend to be slightly higher than in the other programs. In one case the differences between the mean scores in the Discovery program over the means in the Concepts or Control programs reached the .05 level of significance.

3. Critical Thinking, Grades 4, 5, 6

During the year tests were designed to measure such components of critical thinking as Recognition of Assumptions, Relational Logic, Class Logic and Inference. A final form of the test with these scales was administered to a sample of approximately 90 intermediate grade children in each science program and in the control classes. Although small variations did appear, no significant differences appeared between science programs. In the sixth grade a difference was noted between the control group and all three science programs which was significant at the .05 level in favor of the control.

E. Discussion of Results

This analysis has considered the effect of the science programs from several points of view. The results have not been always in agreement nor entirely convincing.

From the teacher's point of view the Process and Concepts programs are judged effective with a need for modification of the Discovery program, particularly in the primary grades indicated. From the parent's point of view, the Process and Discovery programs produced more positive effects in the child's out of school activities. The testing program indicates that improvements in creative thinking were equally frequent in each of the programs and in the control. The level of critical thinking measured was about the same in all programs with the exception of a slight advantage of the Discovery program in the primary grades and the higher scores of the sixth grade control group. While the influence of the curriculum on creative thinking was minimal, the influence of the individual teacher and the question of what teaching behavior produces these effects must be raised.

A major finding resulting from this year's trial is that individual teacher differences in ability, teaching style and motivation are highly relevant factors which must be considered in curriculum modification. An optimum program would seem to require a set of options from which teachers can select the program which best matches their teaching ability and style.

This portion of the report must be ended with a note of caution about interpretation of the results, particularly for those readers outside the Boulder Valley School District. The authors of this report do not consider this year's trial to be a definitive test of the relative merits of the several programs involved.

Many worthwhile outcomes of the science programs were not measured because of time or technique limitation. Among these were the extent to which children acquired process skills, science concepts, and the children's attitudes about science. In each case, the materials were used in a way which was subject to local interpretation, and departures from the intent of the authors of the science programs undoubtedly occurred. The Elementary Science Study materials in particular were modified and supplemented locally. In some cases, materials were used in trial teaching versions which were not ready for general release.

The trial was conducted in the belief that it is better to base decisions on incomplete data rather than on no data at all. The direction for future work in improving elementary science in this school district was more clearly defined as a result.

CHAPTER III - TEACHING STYLE INVESTIGATION

A. Expository-Inductive Observation System

Obtaining the critical-creative thinking objective through the simple curriculum change process appeared unpromising. Yet an influence was being exerted by the teachers, at least insofar as creative thinking was concerned. One apparent problem was that of identifying what components of teaching behavior were contributing to changes in creative thinking. Such a problem led directly to the currently active field of inquiry into the nature of the interactions between teachers and students.

From various frames of reference observers of classrooms have formulated observation schedules and behavior category systems which reduce the data rich environment of classroom to numerical form for analysis. The complexity of the environment, coupled with a multitude of reference frames and theoretical constructs, has resulted in systems of interaction analysis which number well over one hundred (1). After a reasonably thorough search it was concluded that although there were several related systems, such as Flanders (2) Taba (3), none seemed to fit the problem at hand. A particular element of interest, which was missing in existing systems, was the interactions of children with materials constituting the environment of a science classroom.

A relationship should exist between a teacher's style of interacting with the students in a class and the thinking behavior exhibited by the students under the teacher's influence. Students who are typically required to act and produce should be distinguishable from those students who are typically required to accept and reproduce information. The task was, therefore, twofold; first, to develop a system of observation that included the relevant variables of teacher behavior and second to devise a means of measuring the changes in student's thinking. An analysis by Glaser (4) suggested the classification of teaching strategies as inductive or expository and led to the design of the instructional analysis system.

A first dichotomy was established between the general sort of actions by which the teacher manages the activities of a class and the actions which constitute instruction. Management functions include procedural and rapport maintenance tasks and their form should be independent of the subject under instruction.

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(1). Simon, Anita and Boyer, G.E. (Eds.). Classroom Interaction Newsletter, Vol. 4, No. 2, May, 1969.

(2). Flanders, Ned A., Interaction Analysis in the Classroom, A Manual for Observers. University of Michigan, School of Education, Ann Arbor, Michigan, 1966.

(3). Taba, Hilda. Teaching Strategies and Cognitive Functioning in Elementary School Children. San Francisco State College, San Francisco, 1966.

(4). Glaser, Robert. "Variables in Discovery Learning," in Learning by Discovery. Shulman, L. and Keislar, E.R. (Eds.). Rand McNally, 1966.

Instructional functions are classified as expository or inductive described as follows:

1. Expository Teaching $(L) \longleftrightarrow (T) \longleftrightarrow (R)$

The diagram shows interactions between the teacher (T), the learner (L), and phenomenal reality (R). Arrows represent interactions between the components. In this mode of teaching the teacher serves in the role of interpreter, explaining reality to the learners. This includes such activities as asking questions and reinforcing correct responses, answering student questions, citing authoritative sources, demonstrating through the manipulation of equipment and by narrative explanation.

2. Inductive Teaching

$$\begin{tikzcd}
(L) \arrow[rr, leftrightarrow] \arrow[dr, leftrightarrow] & & (R) \arrow[dl, leftrightarrow] \\
& (T) &
\end{tikzcd}$$

The second diagram uses the same symbols to depict interactions under the inductive mode. In this mode the teacher acts to place the student in direct contact with reality. The teacher responds to questions in such a way as to cause the student to search for his own answers. The essential ingredient in this mode of teaching is the circumstance in which students receive feedback from reality without the teacher's interpretation.

3. Event Codes

A more detailed description of the teacher behavior events which were recorded, and the coding utilized, is seen in the following summary.

- I. Instructional Events (Inductive or Expository Teaching Behavior)
    - 1. Manipulates environment
    - 2. Asks question
    - 3. Listens to student
    - 4. Responds to student question
    - 5. Makes statement of fact
    - 6. States opinion
- II. Managerial Events
    - A. Rapport maintenance
        - A+ Positive affective action (encouragement, praise, etc.)
        - A0 Neutral affective action (arbitration of dispute, etc.)
        - A- Negative affective action (threat, display of anger, etc.
    - P. Procedural actions
        - P(1) Verbal procedural instructions
        - P(2) Non verbal procedural actions
- III. Other Events
    - N(1) Uninterpretable event
    - N(2) Missing data (video tape malfunction, etc.)
    - S Silence

A sample observation is as follows:

```
                                                     0 - 0
Interval              0 - 0 - 0                       `0'
____________________________________________________________
                        3, 4, 1, 2, A+, P2
                      1 : 2 : 3 : 4 : 5 : 6 : 7 : 8 : 9
____________________________________________________________
```

This would mean the following sequence: Teacher listens to a student, responds to the student's question, manipulates a piece of equipment, asks a question, encourages the student to try the same manipulation, and oversees the student's activities without comment. The overall rating for the events of the minute is three scale units toward the inductive side of neutral.

The determination of whether an inductive or expository instructional function is being served requires the observation of a sizable amount of behavior and an inference on the part of the observer. As a result of considerable experimentation an observation interval of one minute was selected and a global rating of that interval on a nine position scale from totally inductive to totally expository was made.

The use of such a system clearly requires trained observers. The team of observers in this study consisted of a graduate student in the field of clinical psychology, a graduate student in the field of science education and a fifth grade teacher.

This team collaborated in the development of the observation system and trained themselves in its use by viewing filmed and videotaped exemplars of inductive and expository teaching. A segment of recorded teaching behavior was viewed and rated. The observers would compare their ratings and discuss discrepancies. They would replay the segment and attempt to resolve the differences, explaining what events were cues to the teaching style inferences made. In this manner the team was able to operationally define the rating system and were able to converge to the point that a satisfactory inter-judge reliability (r = .792) was obtained for independently rated videotapes.

B. Critical and Creative Thinking Tests

Several preliminary tests ("Critical Thinking in Science") evolved into the "Boulder Tests of Critical and Creative Thinking in Science." These were constructed to assess changes in the domains of the project's objectives. The nature of these instruments and their origin is described in the following two parts; first, creative thinking or divergent production, then critical thinking or convergent production.

1. Creative Thinking in Science

Taylor(5) has pointed out that students should be considered as "thinkers, producers, and creators rather than solely as learners, recorders or memorizers." This paper proved to be a precursor to a substantial interest within the science education community in the proposition that since progress in science is dependent on creative production, Bronowski(6), Taylor and Barron(7), creativity or divergent production is a significant objective of science education. A book on the topic by Piltz and Sund (8) has appeared and studies on the effects of science instruction on creativity are included in the extensive new literature on the general topic of creativity. Accepting divergent production as a proper objective of education in science suggests the question: "Is it a measurable outcome?" Can means be developed to determine to what extent this objective is being achieved? Work by Torrance (9,10) suggests an affirmative answer to this question and also provides patterns for such measurements. The Torrance pattern was followed in the development of a measure of divergent production within the content of elementary science.

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(5). Taylor, Calvin W. "Scientific Creativity: Its Recognition and Development," Thirteenth Annual Convention of the National Science Teachers Association, Denver, Colorado: March 28, 1965. (Mimeographed).

Eight open response items were developed, two in each of the following categories: guessing causes, asking questions. unusual uses, and improving a tool. These were assembled into two alternative forms (called Form G and Form H of the Boulder Test of Critical and Creative Thinking). The items were designed to pose a problem which was clearly stated but which had a multiplicity of possible solutions. Each item was at the top of a sheet of paper with twenty blank numbered lines underneath. A sample item pair is as follows. Instructions written in capital letters were common to each item.

IMPROVING A TOOL

THIS ACTIVITY WILL GIVE YOU AN OPPORTUNITY TO THINK OF WAYS TO IMPROVE SOMETHING SO THAT IT WILL BE BETTER OR MORE USEFUL.

Form G	or	Form H
A boy needed something to lift pieces of metal out of hot water. He made a tool out of two strips of metal by connecting them together with a boldt. The tool works something like a pair of scissors.		A boy needed something to carry pieces of dry ice. The dry ice is so cold that it would hurt his hand if he held it with his fingers. He made a tool by fastening a tin can lid to a wire handle from an old fly swatter. The tool works something like a spoon.

THINK OF AS MANY DIFFERENT WAYS OF IMPROVING THIS TOOL AS YOU CAN. THE CHANGES SHOULD MAKE THE TOOL EASIER TO USE OR MAKE IT MORE USEFUL A TOOL FOR HANDLING THINGS THAT ARE TOO HOT, TOO COLD OR DANGEROUS TO TOUCH. LIST ALL OF THE WAYS TO IMPROVE THIS TOOL ON THE SPACES ON THIS PAGE. USE THE BACK OF THIS PAGE IF YOU NEED MORE SPACE.

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(6). Bronowski, J. "The Creative Process," Scientific American, Volume 199, Number 3, September, 1958.

(7). Taylor, Calvin W. and Barron, Frank (eds.). Scientific Creativity: Its Recognition and Development. Selected Papers from the first, second and third University of Utah Conferences. New York, N.Y.; John Wiley & Sons, Inc., 1963

(8). Piltz, Albert and Sund, Robert. Creative Teaching of Science in the Elementary School: Boston, Mass.: Allyn and Bacon, Inc., 1968

(9). Torrance, E. Paul. Guiding Creative Talent. Englewood Cliffs, N.J.: Prentice Hall, 1962

(10). Torrance, E. Paul. "Torrance Tests of Creative Thinking," Princeton, N.J.: Personnel Press, Inc., 1966

The text of the item was read aloud by the examiner and the children were allowed 10 minutes to complete each item. A model of one or the other of the crude tools was exhibited during the presentation of the improving a tool item. Since the scoring procedure was developed contemporaneously with the study, the pretest responses were used to produce a scoring procedure for the items. Responses from each pretest booklet were written on a separate slip of paper producing a tray full of approximately 2,500 different responses for each of the eight items.

Three different measures of divergent production were developed out of these responses: fluency--the number of responses; flexibility--the number of different categories in which responses were given; and originality—the statistical infrequency of responses (i.e., frequently given responses scoring low and original or unique responses scoring high). The fluency score was arrived at by simply counting the responses to the item. The flexibility score necessitated sorting the 2,500 responses into empirically determined categories. The categories were then related by imposing a logical structure to reduce overlap between categories and to facilitate test scoring. The flexibility scoring matrix for improving a tool, Form H, is shown in Table IX. The responses for each item were classed in such a category matrix with the number of categories varying from twenty to thirty-five.

TABLE IX. RESPONSE MATRIX PRODUCT IMPROVEMENT - FORM H

Substance Change Function Change	1	2	3	4	5	6
Unspecified		376*	277	517	250	20
Mechanical Properties	214	22	45	117	28	1
Heat Conductivity	188	0	21	13	5	0
Safety	25	2	9	18	2	0
Decorative	19	0	0	1	1	0
Other Functional Changes	18	1	1	3	0	0

1. Unspecified Substance Change
2. Gross Dimensional Deformations
3. Shape
4. Material Addition
5. Material Substation
6. Other Substance Changes

* 376 responses were classed in the category of Gross Dimensional Deformations with no change of function mentioned.

The originality value for each response was determined by further sorting responses until identical or equivalent responses were together. Equivalent responses were those which gave the same solution to the problem but had different wordings or sentence constructions. The number of times a response was given was determined and a frequency distribution plotted. These distributions were J-shaped with a large number of unique responses and typically one response given by one hundred or more students. A standard deviation for the distribution was determined and cutting scores for 1, 2 and 3 sigma units were established. These cutting scores were translated into the following originality weightings.

Occurrence Among 250 Responding	Approximate %	Originality Points
1 or 2	1	3
3 - 11	1 - 4	2
12 - 29	5 - 10	1
30 or more	10	0

The category matrix and originality weightings were assembled into scoring booklets for each item. By that time eight months had elapsed and the alternate forms of the test were again administered as post tests. The scoring booklets were then used to score the original pretest booklets and the post tests.

2. Critical Thinking in Science

Critical thinking has a long history as an objective for education (11) in general and for elementary science education (12) in particular. Efforts at measuring critical thinking have paralleled its inclusion as an objective, leading to Watson and Glasser (13) who produced a five scale test of critical thinking for adults and teenagers and to the work of Ennis (14) who produced tests of class and conditional reasoning for ages 10 to 18.

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(11). Dressel, Paul. "Critical Thinking: The Goal of Education." National Education Association Journal, Vol. 41, 1955, NEA.

(12). Dunning, G. M. "Developing Critical Thinking Through Elementary Science." School Science and Mathematics, Vol. 51, 1951.

(13). Watson, G. and Glasser, E. M. "Watson-Glasser Critical Thinking Appraisal, Manual for Forms YM and ZM." Harcourt, Brace and World, Inc., New York, 1964.

(14). Ennis, R. H. "Critical Thinking Readiness in Grades 1-12 (Phase 1: Deductive Reasoning in Adolescence)." Cornell University, 1964. (Mimeographed project report).

While providing valuable guidance, neither of these sources had produced the appropriate test for the question at hand. The Watson-Glasser tests were designed for an older population of subjects and the Ennis tests were only for deductive logic, an important but not exhaustive component of critical thinking.

Work on an appropriate critical thinking test was begun early in the project. Items were written to fit conceptually into one of the critical thinking scales. The items were then assembled into tests and administered to groups of intermediate grade children. Responses to these early tests were then analyzed by a modified factor analysis (15) to establish what emperical evidence for critical thinking scales supported the conceptual design. Substantial revisions of these tests were made to improve the scaling properties.

The results of this work were tests of twenty-six items in each of three scales called Assumptions, Inference and Reasoning. These scales were parallel to the Watson-Glasser scales "Recognition of Assumptions", "Inference" and "Deduction", respectively. Efforts to produce scales parallel to the Watson-Glasser scales "Interpretation" and "Evaluation of Arguments" were unsuccessful. Forms G and H were parallel forms and were assembled with the forms G and H of the creative thinking items described above. This composite test, identified as the "Boulder Test of Critical and Creative Thinking", was administered in two forty-five minute sessions.

3. Scaling Properties of the Boulder Test of Critical and Creative Thinking

In the teaching style study, the alternate forms of the BTCCT were administered so that half the population took Form G as a pretest while the other half took Form H as a pretest. Similarly, half took Form G as a post test, the other half took Form H as the post test. These data obtained from these administrations were analyzed with a scale scoring program (16) which computes scale variances, scale correlations and two statistics of scale reliability, Chronbach's Alpha (17) and Scott's Homogeneity Ratio (18).

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(15). Tryon, R. C. and Bailey, D. E. (ed.) Users Manual of the BCTRY System of Cluster and Factor Analysis, Tape Version for 709, 7090, 7094 of July 31, 1965.

(16). Jones, Richard. Scale Scoring Program IBS 234, University of Colorado Institute of Behavorial Science, April, 1969 (mimeographed).

(17). Chronbach, J. L. "Coefficient Alpha and the Internal Structure of Tests", Psychometrica, 1951, 16.

(18). Scott, W. A. "Measures of Test Homogeneity", Educ. Psychol. Measurement, 1960, 20.

a. Form G as Pretest, number of subjects n = 286

Scale	Chronbach's Alpha	Scott's Homogeneity Ratio	Items	Mean	Variance
Assumptions	.554	.123	26	.88	.15
Inference	.495	.090	26	.43	.20
Reasoning	.800	.177	26	.68	.20
Fluency	.831	.581	4	9.80	4.68
Flexibility	.681	.356	4	4.37	1.42
Originality	.797	.521	4	11.52	7.44

Scale Correlation Matrix

	1	2	3	4	5	6
1. Assumptions	-	.242	.341	.172	.269	.169
2. Inference		-	.433	.192	.225	.200
3. Reasoning			-	.325	.322	.314
4. Fluency				-	.799	.917
5. Flexibility					-	.781
6. Originality						-

b. Form G as Post test, number of subjects n = 235

Scale	Chronbach's Alpha	Scott's Homogeneity Ratio	Items	Mean	Variance
Assumptions	.583	.136	26	.89	.15
Inference	.587	.125	26	.45	.22
Reasoning	.817	.192	26	.67	.21
Fluency	.829	.570	4	11.15	5.14
Flexibility	.663	.343	4	4.86	1.50
Originality	.731	.416	4	12.87	7.47

Scale Correlation Matrix

	1	2	3	4	5	6
1. Assumptions	-	.238	.254	.207	.215	.199
2. Inference		-	.275	.270	.289	.302
3. Reasoning			-	.274	.343	.323
4. Fluency				-	.798	.904
5. Flexibility					-	.764
6. Originality						-

c. Form H as a Pretest, number of subjects n = 235

Scale	Chronbach's Alpha	Scott's Homogeneity Ratio	Items	Mean	Variance
Assumptions	.570	.135	26	.79	.19
Inference	.669	.155	26	.52	.23
Reasoning	.820	.187	26	.65	.21
Fluency	.835	.575	4	8.84	4.35
Flexibility	.716	.390	4	4.12	1.47
Originality	.786	.494	4	12.19	7.32

Scale Correlation Matrix

	1	2	3	4	5	6
1. Assumptions	-	.409	.409	.177	.262	.151
2. Inference		-	.527	.315	.462	.295
3. Reasoning			-	.304	.397	.273
4. Fluency				-	.829	.922
5. Flexibility					-	.791
6. Originality						-

d. Form H as a Post test, number of subjects n = 286

Scale	Chronbach's Alpha	Scott's Homogeneity Ratio	Items	Mean	Variance
Assumptions	.588	.148	26	.86	.16
Inference	.629	.134	26	.62	.22
Reasoning	.794	.166	26	.71	.18
Fluency	.872	.653	4	10.18	5.28
Flexibility	.722	.409	4	4.63	1.50
Originality	.832	.576	4	12.88	8.42

Scale Correlation Matrix

	1	2	3	4	5	6
1. Assumptions	-	.326	.389	.164	.264	.165
2. Inference		-	.465	.154	.215	.120
3. Reasoning			-	.276	.368	.249
4. Fluency				-	.784	.909
5. Flexibility					-	.829
6. Originality						-

e. Form I was developed by combining forms G and H for a separate purpose. The administration of this test and subsequent analysis provides an opportunity to investigate the relationships between the several critical and creative scales and I.Q., Achievement, and two non-verbal performance measures. This test was administered to 210 fifth and sixth grade students in January 1969 (19). The test properties and interrelationships between it and other measures are shown in the following tables.

Test	Chronbach's Alpha	Scott's Homogeneity Ratio	Items	Mean	Variance
BTCCT Scales					
Assumptions	.721	.104	26	.83	.12
Inference	.550	.046	26	.60	.13
Reasoning	.790	.128	26	.70	.18
Fluency	.710	.443	3	10.23	4.16
Flexibility	.505	.256	3	5.03	1.41
Originality	.682	.419	3	13.53	7.12
Stanford Science Achievement Test	.828	.078	58	.57	.14
Performance Test #1	.686	.053	40	.44	.12
Performance Test #2	.477	.030	30	.44	.11
I.Q. (Lorge-Thorndike Form 2)	-	-	-	110.47	11.43

TABLE XIX

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(19). Mutually Aided Learning Project, Cherry Creek Public Schools, Englewood, Colorado. Albert Thompson, Director.

Correlation Matrix

		1	2	3	4	5	6	7	8	9	10
1.	Assumptions	-	.275	.348	.078	.142	.094	.343	.149	.321	.319
2.	Inference		-	.463	.219	.276	.250	.417	.339	.355	.501
3.	Reasoning			-	.247	.302	.255	.491	.381	.354	.538
4.	Fluency				-	.720	.880	.293	.211	.085	.239
5.	Flexibility					-	.700	.347	.181	.221	.311
6.	Originality						-	.313	.242	.159	.278
7.	Science Achievement							-	.501	.505	.591
8.	Performance Test #1								-	.500	.409
9.	Performance Test #2									-	.425
10.	I.Q.										-

The data above falls short of ideal demonstration of the validity, efficacy, and reproducability of a new testing instrument. The data does show the following, however. First, the tests show reasonably consistent performances over what can be considered five separate administrations. Four of the six scales show a satisfactory homogeneity ratio falling between the .150 and .500 levels. Ratios above the .500 level suggest redundency in the scale so that items might be deleted with no loss of information. Ratios below .150 suggest the items in the scale do not measure a single unitary trait. The reliabilities (Chronbach's Alpha) are reasonable considering the length of the test scales. Doubling or tripling the number of items per scale would raise these values considerably but at a substantial cost in testing time required. For the purpose at hand, it was considered better to proceed with six relatively independent scales with roughly .7 reliabilities than to utilize all of the available testing time on a single trait even if the reliability of it could be raised considerably higher.

C. Results of the Teaching Style Study

The two tools described in this chapter were developed to be applied to the question of whether the source of the teacher's influence on creative thinking could be identified.

To this end a sample of fourth, fifth and sixth grade teachers was drawn randomly from those participating in the project but not included in the first year's testing program. These teachers and the principals of their schools were contacted, the investigation was explained and participation was requested. Of the twenty-four in the initial sample, twenty teachers and their principals agreed to permit the testing and video-taping of their classes.

Several important precautions were taken to insure the success of this relatively sensitive undertaking. The video-taping schedule of classes in the teaching style study was merged with the video-taping of exemplary teaching for use in in-service education. Being selected for video-taping was therefore a relatively prestigious event. Anonymity was assured in the reporting of the findings and each teacher had the right to review each tape and to order it erased if unacceptable.

Complete data was collected for eighteen classes. The video-taping was done with a Sony 2000 Video-tape Recorder mounted on a wheeled dolly so that it could be rolled from one position to another within the class while recording. The sound reception was augmented with a "cordless" FM transmitting microphone worn by the teacher.

Approximately sixty minutes of teaching was rated for each teacher. The raters followed the procedure described above and assigned an overall rating for each minute on the expository-inductive continuum. These values were averaged, yielding a score for each teacher. As noted before, the inter-judge reliability of the ratings was .792.

Questions of interpretation arose concerning these scores. A 5 rating might mean either that a teacher alternates between inductive and expository styles or that neither style was observed. On review of the data, it became apparent that large fluctuations between inductive and expository styles were not observed. There were consistent uses of a particular style among teachers on both ends of the continuum. Further, the raters agreed that the 5 rating was used essentially as a neutral one suggesting that the behavior observed did not fit the expository-inductive model. As a consequence, the teachers were divided into three groups labeled expository, indeterminate and inductive, and the analysis was made on this basis. Forms G and H proved to be significantly different in difficulty so an adjustment was made by adding an appropriate constant to the mean of each scale.

Adjusted difference scores were computed on a scale by scale basis by subtracting pretest from post test scores.

These difference scores were then analyzed by means of a one-way analysis of covariance with dicotomized pretest scores as the covariate. The results are shown in the following table.

Percentage Change in Scale Scores

Scale	Expository Style	Indeterminate Style	Inductive Style	F Ratio	Significance Level
Assumptions	+ 1.7%	- 2.9%	+ 1.0%	3.18	.95
Inference	- 0.8%	+ 1.3%	+ 2.2%	1.19	ns
Reasoning	+ 0.9%	- 4.1%	+ 3.0%	8.87	.99
Fluency	+ 6.2%	- 9.5%	+ 2.4%	6.26	.99
Flexibility	+ 4.5%	- 4.3%	- 0.9%	4.26	.95
Originality	+ 4.0%	-14.1%	+ 9.2%	9.57	.99

TABLE XXI n = 519, 2 and 515 degrees of freedom

The most striking outcome is the difference in changes in scores obtained by children in the classes rated as indeterminate which were predominately losses, while gains occurred in both classes rated as expository and classes rated as inductive. In brief, it appears that benefits obtain to children in classes where the teacher displays a teaching style but that it doesn't seem to matter if that style is expository or inductive. The differences are most noticeable in the creative thinking scales.

There are several interpretations of these results that could be made. The simplest is that teachers who design and carry out instructional sequences which have apparent direction and organization produce good effects on the students' thinking abilities. An alternate interpretation applicable particularly to the creative thinking scales has to do with consistency and inconsistency. Inductive or expository ratings were associated with consistent performances by the teachers. Children in classes where the teacher is consistent should feel more freedom to respond in original or humorous ways when asked, while children in classes where the teacher is less predictable would be more constrained in giving original responses.

CHAPTER IV - SCIENCE PREFERENCES OF TEACHERS

Curriculum designers have produced science materials which deal in different ways with the problems generated by rapid technological change and exponential growth of knowledge. The diversity of approaches to elementary science seems to be due to differing psychological and philosophical frames of reference of the curriculum designers, and the trial use of new science materials suggested that these different frames of reference are repeated among the project teachers. Many of the differences appear to be deep-seated and not susceptible to easy modification.

Data from the first year's trial did not support a single program over the others and a significant fraction of the teachers encountered difficulty with each program. The most promising course of action appeared to be recognition of the substantial individual differences among teachers by providing them a choice of program. In order that the choice be an informed one, teachers not participating in the project were invited to in-service sessions where they engaged in activities representative of the programs.

On May 2, 1968, a questionnaire was distributed to all teachers of grades one through six, asking them to indicate their selection between two alternative science curricula. The two programs are described in the following paragraphs.

> Science Concepts - This program includes the Harcourt, Brace and World Concepts in Science text series and associated laboratory kits. Texts will be available on an individual student basis and the laboratory materials are available in such quantity that investigations can be done by the teacher or by groups of students on a demonstration basis. At each grade level units are provided in each of six conceptual schemes.
>
> Science Skills and Discovery - This program includes units selected from the material produced by AAAS and ESS. In grades 1, 2 and 3, an emphasis on process skills will predominate but some time will be spent on discovery activities. In grades 4, 5 and 6, emphasis will be placed equally on process skills and scientific inquiry. Laboratory materials will be sufficient to have students working individually, in twos, or teams of five or six. Reading will be limited to reference material as a text is not used.
>
> The results of this selection are shown in Table XXII.

Grade	Science Concepts	Science Skills & Discovery
1	50%	50%
2	48%	52%
3	57%	43%
4	46%	54%
5	26%	74%
6	40%	60%

TABLE XXII Percent of 392 Teachers Choosing Different Science Programs, 1968

On the basis of this information, it is clear that sizable proportions of the teachers at all grade levels preferred each of the two programs.

In order to accommodate the differences in situation and instructional style and to provide material with which the instructional staff had confidence, adoption of both programs as alternatives was accomplished for the 1968-69 school year.

Again in the spring of 1969 a similar questionnaire was distributed offering the same two alternatives for the 1969-1970 school year.

The results of this second selection are shown in the following table.

Grade	Science Concepts	Science Skills & Discovery
1	57%	43%
2	56%	44%
3	69%	31%
4	60%	40%
5	41%	59%
6	52%	48%

TABLE XXIII Percent of 408 Teachers Choosing Different Science Programs, 1969

The concepts choice shifted from slightly less than half in 1968 to slightly more than half in 1969. The profile remained essentially the same with the fifth grade choice consistently more toward the non-text choice than any other grade.

With the shifts in science curriculum occurring as a result of teachers exercising their options, the opportunity of comparing non-text and text choices in the schools used in the first year's trials presented itself. In the intermediate grades about half of the teachers were using the text approach but they were now distributed among all the schools. It was thus possible to examine any differences resulting from a combination of the text program with teachers who chose the text program compared to the non-text program as used by teachers who chose that program.

Form I of the "Boulder Test of Critical and Creative Thinking" was available and in addition the STEP Science Achievement Tests (20) were obtained.

Thirty-six classes were selected from the schools in the initial comparison by choosing six text and six non-text classes at each grade--fourth, fifth and sixth. This gave a student population of slightly over 700. The classes were tested in May, 1969.

The results are shown in Table XXIV.

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(20). Educational Testing Service, "Sequential Tests of Educational Progress, Science, Forms 3A and 4A". Princeton, N. J., 1962.

	Grade 4	Grade 5	Grade 6	Non-Text	Text	Confi-dence Level
1. Assumptions	17.9	20.7	23.5	22.9	18.5	.99
2. Inference	12.6	14.4	15.3	15.2	13.0	.99
3. Reasoning	24.4	26.9	32.7	31.2	24.8	.99
4. Fluency	17.0	17.0	17.9	17.3	17.4	ns
5. Flexibility	11.9	12.8	13.9	13.5	12.3	.99
6. Originality	13.4	14.0	15.5	14.7	13.9	.95
Critical Thinking Scales 1, 2 and 3	54.7	62.3	71.4	69.2	56.4	.99
Creative Thinking Scales 4, 5 and 6	42.4	43.6	47.1	45.2	43.5	.99

TABLE XXIV 1968-69 Comparison of Text and Non-text Science Programs, N = 729

The results of the achievement testing are shown in Table XXV. Level 4A was administered to the fourth grade students and level 3A was administered to fifth and sixth grade students. The data in the table are presented in converted score form to provide for comparability between the two levels.

	Non-text	Text	Confidence Level
Fourth	269.8	271.0	ns
Fifth	283.2	273.9	ns
Sixth	276.9	278.3	ns
Total	276.6	274.4	ns

TABLE XXV STEP Science Achievement Converted Scores

The data suggests that the combination of non-text science program coupled with teachers who elect that program is superior to the non-text program with respect to improving critical and creative thinking and with no loss in the area of science achievement as measured by the STEP Science Achievement Test and the BTCCT.

CHAPTER V - EFFECTIVENESS OF INSTRUCTIONAL STRATEGIES

A. Introduction

The obtaining of adequate criteria has proven to be of major concern in the evaluative efforts of this project. Subtile but important changes in childrens' thinking were believed to occur when children were actively involved in manipulating materials in the environment; but data obtained from testing of the pencil-paper variety was meager in its support of this belief. An article by Smedslund (21) describes a method of determining qualitative differences between children who learn the conservation of substance concept under different circumstances. The conservation phenomena were first described by Jean Piaget and his co-workers in Geneva. A description of the conservation of substance experiments is available in English translation from a 1941 book by Piaget (22).

Briefly, a child has conservation of substance when he thinks the amount of substance, in a clay ball for example, remains constant even though the substance is radically altered in shape, say rolled into a long snake. Non-conserving children tend to focus their attention on a single attribute of the new configuration and support their belief that the amount of substance is different by compairsons like "it is longer now". Conservers tend to support their contention with either equivilence arguments, "you didn't add any or take any away" or reversibility arguments, "the snake could be rolled into a ball and it would be the same again". The typical age of the acquisition of conservation of substance is seven and one half years, but there is a substantial variance due to individual differences.

Because of the relevance of conservation acquisition to both psychological and educational issues, a substantial amount of reasearch has been directed at the problems involved. Training procedures have been developed and generally positive but not outstanding effects of training have been observed.

Smedslund's extinction procedure was designed to test the quality of the conservation concept obtained by training. He first trained children to give conservation responses consistantly. He then produced effects apparently contrary to conservation, for example, by making the snake shape also heavier by unobtrusively adding a marble. These extinction events caused children who had acquired conservation through training to quickly revert to non- conservation interpretations. Children whose conservation was acquired "naturally" were much more resistant to extinction.

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(21) Smedslund, Jan, 'The Acquisition of Conservation of Substance and Weight in Children: III Extinction of Conservation of Weight Acquired 'Normally' and by Means of Emperical Controls on a Balacce", Logical Thinking in Children, Sigel, Irving E. and Hooper, Frank H. (eds). Holt-Rinehart-Winston, Inc., New York, 1968, (Reprinted from Scandinavian Journal of Psychology, 1961, 2, 85-87.)

(22) Piaget, Jean, The Child's Conception of Number, Routledge and Kegan Paul Ltd. London, 1952.

The Smedslund extinction procedure appeared to be the sensitive sort of criterion needed to detect differences in childrens' thinking resulting from the alternative instructional strategies which underlie the direct or discovery modes of science instruction. A third possibility imbeded in Smedslund's "natural" conservation acquisition is that children learn most readily from their peers.

Three first grade teachers in rented class space detached from other classes were interested in participating in such a study. Their classes provided a subject pool of 83 students ranging in age from 6; 1 to 7; 5 with a median age of six years nine months at the time of the investigation (February 1969). Substitute teachers were employed to release the teachers for the time necessary to do the individual instruction required.

B. Problem:

The question under investigation was do different learning situations produce differential effects in the permanence of acquired conservation of substance. The learning situations are describes as follows:

1. Direct: The principles and concepts requisite to conservation are presented by the teacher to individual children in a direct manner. The child is questioned and receives verbal reinforcement for conservation responses. Non-conservation responses are allowed to extinguish through non-reinforcement.

2. Materials: Problem situations involving conservation are posed by the teacher. The child is asked to make predictions regarding the equivilence of transformed quantities and the accuracy of the predictions are tested by the child by comparisons on an equal arm balance.

3. Peer: Confrontations between a non-conserving child and a conserving child are produced by having the teacher present a problem and ask for agreement on predictions by the team.

C. Procedure:

Conserving and non-conserving children were identified by administering the six item conservation of substance sub-scale of the Boulder Picture Test. A paper describing this test is appended. In the initial population of 87 first grade students, 45 were classified as non-conservers, 19 were classified as conservers, the remaining 23 had intermediate scores making classification less certain and were excluded from further study.

Forty of the non-conserving children were randomly assigned to three treatment groups and a control group. The peer group had team mates matched by sex and age from the group identified as conservers.

Two of the first grade teachers learned the three instructional procedures and each of them conducted instruction sessions for five children in each of the three treatment groups. They alternated their instructional procedure in the sequence Direct-Materials-Peer.

Sixteen conservation of substance tasks were developed for the instructional sessions. They were presented in the order in which they are listed in Table XXVI.

Task	Substance	Initial Configuration	Final Configuration
1.	beads	two tall thin glasses	one tall thin glass one short wide dish
2.	clay	two large balls	one large ball of clay six small balls of clay
3.	water	two vertical half-full vials with caps	one vertical vial one horizontal vial
4.	beads	two short wide dishes	one short wide dish one tall thin glass
5.	water	two horizontal vials with caps	one vertical vial one horizontal vial
6.	clay	two large balls	one large ball one long thin cylinder (hot dog)
7.	water	two tall thin glasses	one tall thin glass one short wide dish
8.	beads	two sets of six small glasses	one set of six small glasses one large glass
9.	clay	two long thin cylinders (hot dog)	one long thin cylinder one large clay ball
10.	water	two short wide dishes	one short wide dish one tall thin glass
11.	beads	two vertical half-full vials with caps	one vertical vial one horizontal vial
12.	clay	two large balls	one wide thin cylinder (pancake) one large ball
13.	water	two large glasses	one large glass six small glasses
14.	beads	two vertical tall thin vials with caps, filled	one vertical one horizontal vial
15.	clay	two wide flat cylinders (pancakes)	one wide flat cylinder one large ball
16.	water	two sets of six small glasses	one set of six small glasses one large glass

Table XXVI Conservation of Substance Tasks. The clay balls were grey plasticene about 8 cm in diameter. The water was colored with green food coloring. The beads were pink plastic about 4 mm in diameter and approximately 200 were required to fill one of the glasses. The weight of a set of six small glasses equaled the weight of one large glass so that they would balance empty.

A written procedure for each task with each instructional method was followed by both teachers. The procedures for the first task are as follow

Direct

Produce 2 tall thin glasses and pitcher of beads. LET'S FILL THESE TWO GLASSES WITH THE SAME AMOUNT OF BEADS. Fill two glasses with beads. IS THE AMOUNT OF BEADS THE SAME OR DOES ONE GLASS HAVE MORE THAN THE OTHER. Have S move beads until he is satisfied that the amount is the same in both containers. NOW SUPPOSE I POUR THE BEADS FROM THIS GLASS (indicate) INTO THIS SHORT, FAT DISH. WILL ONE HAVE MORE THAN THE OTHER NOW OR WILL THEY BE THE SAME? Record prediction. WHY? Record response. For conservation response. I AGREE. For non-conservation response. BUT THIS GLASS IS ALSO NARROWER. Pour beads. NOW IS THE AMOUNT OF BEADS THE SAME IN EACH GLASS OR DOES ONE HAVE MORE THAN THE OTHER? Record response. WHY? Record response. For conservation. I AGREE. For non-conservation. BUT IF I POUR THE BEADS BACK THE AMOUNT WILL STILL BE THE SAME. Restore to original condition.

Materials

Produce 2 tall glasses and pitcher of beads. E & S jointly manipulate. LET'S FILL THESE TWO GLASSES WITH THE SAME AMOUNT OF BEADS SO THAT THEY BALANCE. Have S move beads until satisfied that they balance. Remove both from scale. Produce short wide dish. NOW SUPPOSE WE POUR THE BEADS FROM THIS GLASS INTO THIS DISH. WILL THEY STILL BALANCE? Record prediction. WHY? Record response. LET'S DO IT. Pour beads off scale and before placing on the scale ask. NOW WILL THIS DISH BALANCE THIS GLASS? Record response. Place on balance. WHY DID THAT HAPPEN. Record response. IS THE AMOUNT OF BEADS THE SAME NOW OR DOES ONE HAVE MORE THAN THE OTHER? Record response.

Peer

Produce 2 tall thin glasses and pitcher of beads. E only manipulates materials. I'M GOING TO FILL THESE TWO GLASSES WITH THE SAME AMOUNT OF BEADS SO THAT THEY BALANCE. Move beads until S's are satisfied that they are balanced. Remove both from scale. Produce short wide dish. Now SUPPOSE I POUR BEADS FROM THIS GLASS INTO THIS DISH. WILL THEY STILL BALANCE? DISCUSS IT WITH EACH OTHER UNTIL YOU AGREE, THEN I'LL ASK ______(S's name) WHAT YOUR ANSWER IS. Record prediction. WHY? (_____S's name). Record response. WATCH ME DO IT. Pour beads off scale. Before placing on scale ask: NOW WILL THIS DISH BALANCE THIS GLASS? DISCUSS IT WITH EACH OTHER UNTIL YOU AGREE. THEN I'LL ASK ________ WHAT YOUR ANSWER IS. Record response. Place on balance. WHY DID THAT HAPPEN? Ask this of non-conserver. Record. IS THE AMOUNT OF BEADS THE SAME NOW OR DOES ONE HAVE MORE THAN THE OTHER? Ask this of non-conserver and record.

Instruction continued using each task in turn until the child gave four sequential conservation responses. The number of trials to criterion was recorded.

At the beginning of each instructional session pretraining with the use of the balance was given.

Two weeks after the training was completed, the extinction trials were conducted by an investigator who did not know to which treatment the children had been assigned. The extinction procedure is as follows:

Extinction Trials

> Produce 2 balls of clay and scale. LET'S MAKE THESE TWO BALLS OF CLAY HAVE THE SAME AMOUNT OF CLAY SO THAT THEY WILL BALANCE ON THE SCALE. Have S manipulate clay until satisfied that they balance. Remove both balls from the scale. NOW SUPPOSE WE MAKE SIX LITTLE BALLS FROM THIS (indicate right) BIG BALL. WILL THE SIX LITTLE BALLS BALANCE THE OTHER BIG BALL? Record response. LET'S DO IT. E divides one large ball into six small balls unobtrusively removing a portion of the clay and retaining it in his hand, replaces clay on the scale. DO THEY BALANCE NOW? Record response including any expression of surprise or disbelief. WHY DON'T THEY BALANCE NOW? Record response, noting any reoccurrence of non-conservation explanation.
>
> Produce two new balls of clay. LET'S TRY THAT AGAIN. MAKE THE AMOUNT OF CLAY IN THESE BALLS EQUAL SO THAT THEY BALANCE. Have S manipulate clay until satisfied that they balance. Remove both balls from the balance. NOW SUPPOSE THAT THIS TIME WE ROLL THIS BALL (indicate left) INTO A LONG HOT DOG SHAPE. WILL THE HOT DOG SHAPE BALANCE THE BALL? Record response. LET'S DO IT. E rolls one large ball into a long cylinder shape and unobtrusively inserts a steel ball bearing. E replaces clay on the scale. DO THEY BALANCE NOW? Record response including any expression of surprise or disbelief. WHY DON'T THEY BALANCE NOW? Record response noting reoccurrence of non-conservation explanation.

At the conclusion of the second extinction trial, the clay was manipulated so that the ball bearing was noticed by the child. Upon this discovery the operations were repeated until conservation responses were restored. Fifty children were observed under the extinction conditions; ten each from the three instructional treatments, ten from the control group which received no instruction and ten initially conserving peers. The criterion trials were videotaped and the videotapes were used to confirm the scoring made during the trials and were also scored by an independent observer.

D. Results

1. Efficiency: The mean number of tasks completed before the four conservation response criterion is shown in Table XXVII. A two way analysis of variance gives F ratios of 2.11 for interaction, 3.26 for teacher effect, and 2.06 for treatment effect, none of which are significant at the .95 level of confidence which requires a F ratio of 3.40.

	Teacher I	Teacher II
Direct	15.80	5.20
Materials	5.60	4.60
Peer	6.80	6.20

Table XXVII. Mean trials before criterion for conservation instruction. N = 30, 5 per cell.

2. Effectiveness: Two measures of the permenance of the instruction were obtained from the extinction trials. First a global rating of 1 for no extinction and 0 for extinction of conservation was determined for each of the 50 children. Table XXVIII shows the number of children resisting extinction for each cell. F ratios obtained from a two way analysis of variance were 1.059 for interaction, .471 for teacher effect and 6.471 for treatment effect. Since a critical F at the .99 level of confidence is 3.83, the treatments, can be considered significant.

	Teacher I	Teacher II	Total
Control	1	0	1
Direct	2	3	5
Materials	4	5	9
Peer	4	2	6
Conserving Peer	5	4	9

Table XXVIII. Number Resisting Extinction of Conservation Concept.

Since only the Direct, Materials and Peer groups represented instructional treatments a second analysis was done excluding the control and conserving Peer groups. In this analysis othe F ratio for treatment was only 2.00 with a 3.40 required to be significant at the .95 level of confidence.

A second measure of the permanence of instruction was obtained by adding the scores for the two predictions and two explanations obtained from the two trials. Table XXX shows the mean scores obtained. The maximum score obtainable is 4.00.

	Teacher I	Teacher II	Total
Control	.80	.60	.70
Direct	2.20	1.40	1.80
Materials	3.40	3.40	3.40
Peer	3.00	2.00	2.50
Conserving Peer	3.80	3.00	3.40

Table XXX. Mean Conservation Scores During Extinction Trials.

A two-way analysis of variance of this data yielded F ratios of .382 for interaction, 3.187 for teacher effect and 10.675 for treatment effect. A critical F for this analysis was 3.83 at the .99 level of confidence so the treatment effect can clearly be considered significant.

Again deleting the Control and Conserving Peer groups and repeating the analysis gives F ratios of .488 for interaction, 1.884 for teacher effect and 4.488 for treatment effect. Critical F ratios at the .95 and .99 levels of confidence are 3.40 and 5.61 respectively, indicating that the instructional treatment did produce significant effects at the .95 level of confidence.

There were clearly observable behavioral differences between children who resisted extinction of conservation and those who did not. Some children quickly and confidently went back to non-conservation explanations suggesting that although they learned to give the right verbal responses, they had not internalized the concept to the extent that they really believed in conservation. Other children looked for something wrong with the apparatus, looked to see if something had dropped on the floor, or otherwise indicated that they had a strong belief in the concept.

Since more of the children who acquired their conservation concept through their own predictions about, and use of materials, this approach appears most effective.

CHAPTER VI - CONCLUSION

This report will conclude with summary statements about the extent to which project objectives were met. These statements are derived in part from the report of an On-site Evaluation Team from the Colorado State Department of Education which visited the Project May 7 and 8, 1969 (23).

A. Establishing An Exemplary Elementary Science Program

In the words of the On-site Evaluation Team, "The Project has succeeded in introducing a vital energetic program of science in the Boulder Valley elementary schools. The Program has stimulated considerable enthusiasm for and interest in science among students, teachers, administrators, and parents."

The Project has served as an example to other school districts. Project staff and teachers traveled to other districts (mainly in Colorado, but also in Kansas and South Dakota) to conduct workshops in elementary science for teachers. Presentations were made at two national, three regional, and three local conventions. Visitors to the Project classrooms numbered 128, and three articles were published.

On the other hand, also in the words of the Evaluation Team, "Lack of participation by some teachers works against the Project." The change strategy of involving teachers as co-reachers in the Project, while successful with many, failed to involve a sizable fraction (perhaps 20 per cent) in a satisfactory way. There are several causes that could be cited. As the number of participating teachers increased, the influence of the staff was diluted. Budget reductions cut severely into the later phases of the Project reducing the amount of in-service education precisely at the time that expansion was needed. Ragged distribution of materials was almost certain because of the accounting requirements of the grant. Funds could not be encumbered prior to trial budget negotiations and the beginning of the Project fiscal period, usually August 1. The chances of having materials into the schools by the beginning of September were slim. Added to the basic acquisition time were vendor delays typically measured in months since the materials were new.

B. Increasing Teachers' Understanding of Critical and Creative Thinking

A consistant theme throughout all of the teacher education activities of the Project was that science can be used as a vehicle to improve children's critical and creative thinking. The information communicated initially came from extensive literature on creative thinking and critical thinking; later, the work of the Project was also included. The teachers involved in the several investigations were particularly motivated to learn what was being measured when their class was tested, how it was measured, and why. A dozen newsletters on these and other topics were distributed to all teachers in the District. While documenting data was not collected, it can be concluded that in the minds of participants creative thinking is no longer an outcome exclusively of the fine arts and both the definition of and means of obtaining critical thinking have been better operationalized.

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(23) On-site Evaluation Team members included Don A. Green, Colorado School District No. 11; Dr. Harold M. Anderson, University of Colorado; and Albert R. Thompson, Cherry Creek Public Schools.

C. Identifying Instructional Strategies Which Elicit Creative and Critical Thinking

Chapters IV and V described to what extent these instructional strategies were isolated. It is clear that the adoption, purchase, and distribution of materials with stated or implied instructional strategies falls far short of insuring that the strategies will be implemented. In-service education with that implementation as a goal may also not succeed. In point of fact, curriculum change in elementary science involves a complex interaction of a teacher's values and skills with materials developed with certain assumptions about values and skills within a school setting which has also certain expectations about student and teacher roles. When any of these factors are in substantial disagreement, the result will be different than anticipated.

Changes in teaching style are possible and have been produced. Some very flexible people can alter their teaching style at will. Most need a model to emulate and something like video tape feedback to compare their own teaching to the model. Preservice or apprentice programs with such an emphasis would prove invaluable as would continued in-service work.

Evaluation efforts have ranged from the broad and diffuse efforts of Phase II, which utilized group testing and questionnaire methods, to the sharper but narrow efforts of Phase IV, focusing on a single concept with a marginally small population.

The project could have followed many patterns differnt from the one that did evolve. For example, selecting one elementary science curriculum and spending the resources of the project "selling" that choice would have produced a different outcome.

The path chosen was prompted by the belief that the objectives of the Project, as well as broader educational aims, are better accomplished in classrooms, schools, and school systems that are open and adaptive rather than standardized and prescriptive.

Boulder Valley School District, Re-2
Boulder, Colorado

Development of A Group Measure to Assess the Extent of Pre-logical and Pre-causal Thinking in Primary School Age Children*

Joseph A. Struthers
Edward De Avila

March, 1967

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54

Introduction

In the Boulder School District we have under way a project to modify our elementary science program by making extensive use of the products of various curriculum development projects. Among several outcomes we are particularly interested in what effect, if any, these changes have on children's ability to think critically. Critical thinking in high school age or older persons has been measured successfully, most notably by the Watson-Glaser tests (1964), but when the question of critical thinking by younger children is raised there is no such ready guideline for defining and measuring critical thinking. In addition, the recently much discussed contributions of Jean Piaget seem to suggest that critical thinking of younger children differs not only quantitatively but also qualitatively from the Watson-Glaser formulations.

Such considerations have led us to attempt to design a group measure of the thought processes which might be seen as the developmental precursors to the reasoning required in critical thinking. This has necessitated the adoption of certain Piagetian conceptual reference frames, but at the same time practical considerations have forced the development of radically different methodology.

As is well known the experimental work of Piaget is founded on the "clinical method" (1963) which involves the extensive interviewing of each subject. One of the immediate concerns regarding Piaget's use of the clinical method is that both the test and inquiry procedure is quite variable for each subject and highly dependent on the skill and sensitivity of the interviewer. Though we would agree with Piaget on the richness of the information that this approach yields, the method was not seen to be feasible for the present purpose because of the large numbers of children involved.

The task of developing a group measure of children's ability to deal with Piaget type tasks was undertaken. A group of thirty or so situations, drawn from Piaget experiments, were identified and subsequently restructured into a cartoon panel format similar to the example on the following page. In this cartoon two boys are engaged in conversation and in actions relating to the task. The story is incomplete and the task for the child is to indicate which of the three choices best completes the story. The present form of the test contains twenty-six such items which represented four conceptual classes of tasks.

In the testing situation the reading difficulties were overcome by having the test administrator read the captions while pointing to a projected image of page while the children followed in their test booklets.

Conceptual Design

Four domains of thought seemed particularly germane to the development of critical thinking. These four concepts were conservation, causality, relations and logic and were contained as sub-scales in the first form of the test. These scales are described in the following.

1. Conservation: The concept of conservation, as described by Piaget, is divided into five distinct types, (1) conservation of substance, (2) conservation of number, (3) conservation of volume, (4) conservation of distance, and (5) conservation of surface. The concept of conservation requires that the recognition of transformations of location, shape, position and so on are not related to changes in the amount of substance, distance, or volume in question. For example, changing the shape of a ball of clay from a ball to a pancake does not alter the amount of clay originally contained in the ball despite the obvious changes in dimensions.

2. Causality: Children are reported to interpret reality in ways different from the objective and mechanistic way of adults. These diverse ways are called precausal explanations and included are animism, dynamism artificialism among others. For example, a child who reasons precausally might well explain the fact that smoke tends to rise on animistic grounds. That is, smoke goes up because "it wants to."

3. Relations: The concept of relations has to do with the child's ability to perceive the relative nature of observations. That is, whether an object is on the right or left side of another object is contingent on the observer's point of view. Other relations such as family relations and order relations also are dependent on the reference frame. For example, whether a person is a father or a son is relative to the person being made reference to in a particular context.

4. Logic: The logic scale consisted of class logic items and items which depended upon the transitive property of the greater than relation. In addition to Piaget (1958) the work of Innis (1964) was used as a guide in the structure of the items.

RESULTS

Test Analysis - 1,972 tests were scored from the first administration. Data was subjected to a factor analysis utilizing the BC-TRY (Tryon, 1966) system. The BC-TRY cluster analysis is an empirical method for determining the interitem consistency within a set of items which go to make up a factor, cluster or scale. The system was thus used to empirically determine the interitem consistency within our conceptual scales. Two of the conceptual scales, namely, conservation and causality, appeared to hold together. The logic and relations scales, while showing some internal consistency, appeared to contain items which were too dissimilar and, as a result, failed to cluster satisfactorily. A fifth scale, called the residual scale, appeared in the empirical analysis, yet did not show any conceptual consistency. The following table summarizes some of the statistical properties of each scale and the total test.

Scales	Homogeneity Ratios	Reliability Coefficient	Mean Score	Standard Deviation	Number of Items
Conservation	0.276	0.694	.71	.28	6
Causality	0.239	0.550	.86	.23	4
Relations	0.001	0.001	.41	.33	2
Logic	0.047	0.227	.50	.22	6
Residual	0.120	0.350	.62	.26	4
Total Test	0.105	0.717	.64	.17	22

As can be seen the conservation scale had six items, a homogeneity ratio of .276, a reliability of .694, a mean score of .71 and a standard deviation of .28. The homogeneity ratio is based on Scott (1960) and provides a measure of the internal consistency of the conceptual scales as contrasted with the purely empirically determined scales derived by the BC-TRY. The reliability measure is Chronbach's alpha (1951) and provides a measure of reliability which is expressed as the mean of the split-half coefficients which are computed for all possible divisions of the test or scale into two parts.

Age Normative Findings. Mean scores on the conservation and causality scales were computed as a function of chronological age to see if developmental trends existed. Figure 1 shows the percentage of students who equalled or exceeded the criterion score for conservation of substance. The curve indicates that the conservation of substance concept develops in the primary grades, however, approximately twenty percent of the youngest children tested appeared to have the concept while approximately twenty percent of the oldest children tested did not.

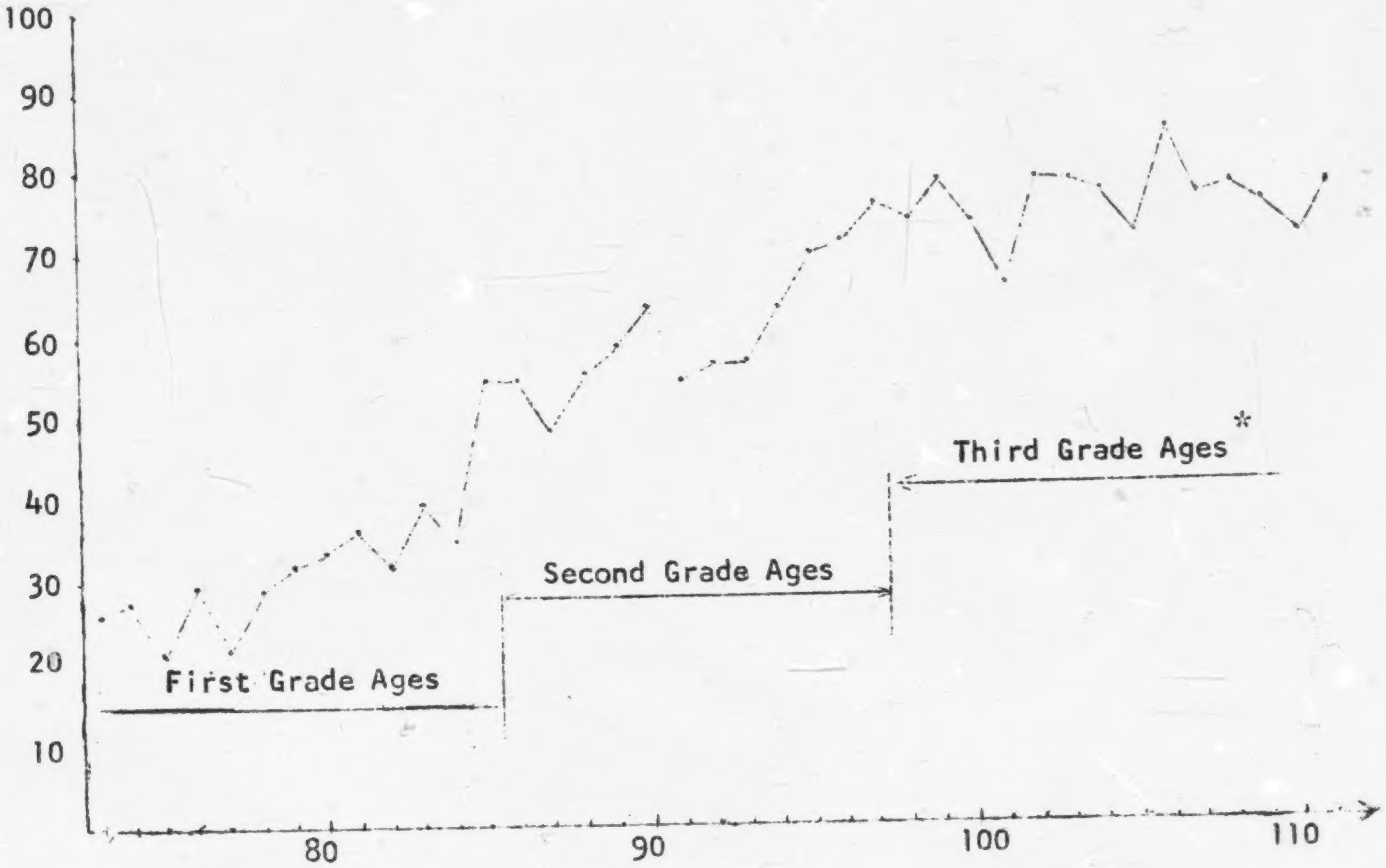

Figure 1 - Mean Scores on Conservation of Substance Scale as a Function of Age in Months.

*The grade level markings indicate normal age in grade at the time the test was administered.

Figure 2 shows the incidence of selection of precausal forms of explanation. Only 14% of the responses used precausal explanations but there were age differences in the incidence and type of selection. Finalistic precausal explanations were selected most frequently followed by dynamistic, animistic, artificialistic and realistic forms. All showed a decrease in use with age except for dynamism in which a slight increase with age can be detected.

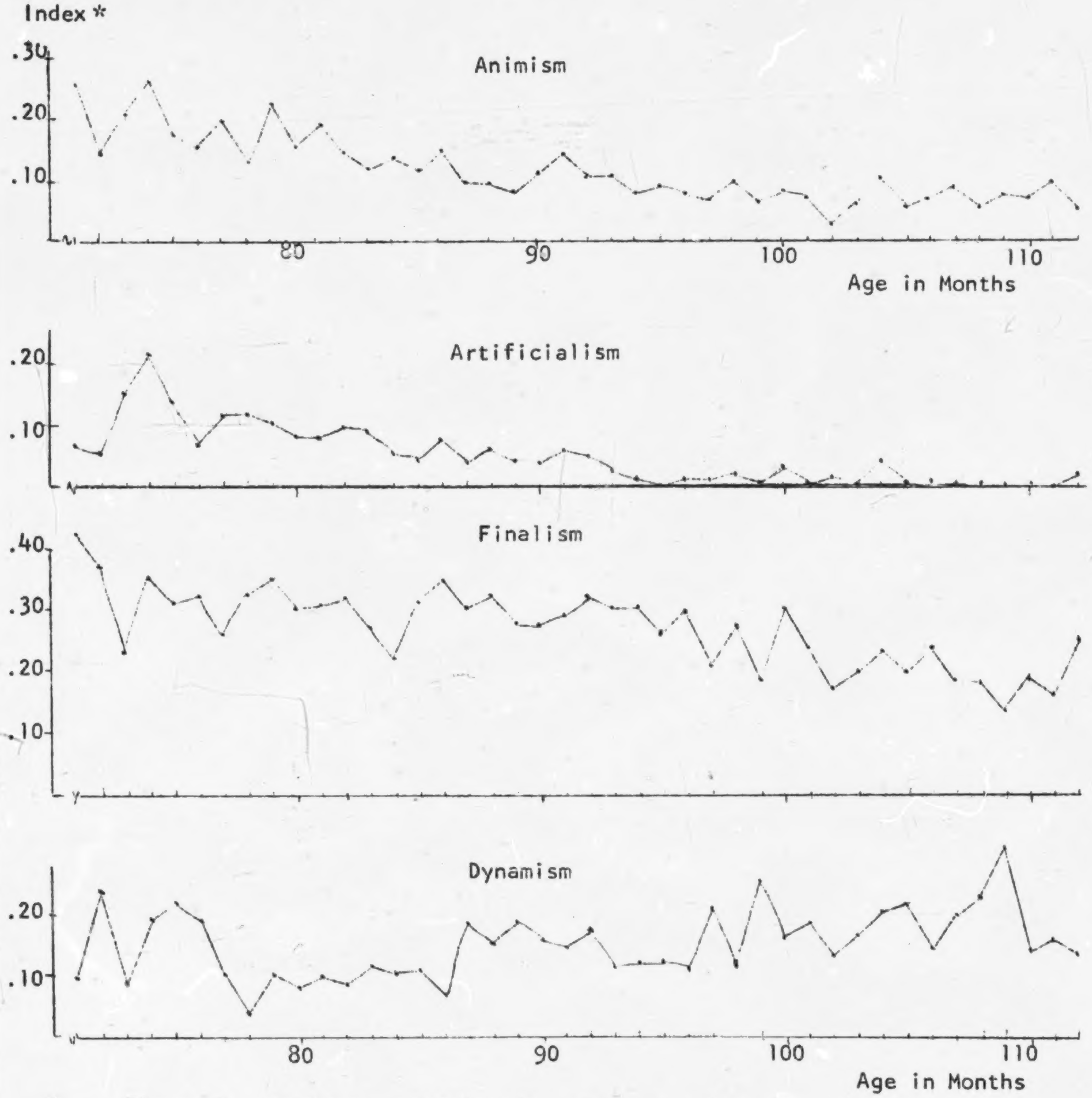

Figure 2 - Incidence of Selection of Precausal Explanation by Type as a Function of Age

*An index of 1.00 would mean every child of a given age in months picked precausal explanations of a particular type each time that type was available as a response.

DISCUSSION

The information derived thus far indicates that the test technique is a promising means for obtaining information about certain aspects of an individual child's thinking which has been obtained heretofor only clinically.

The age normative data obtained on the acquisition of conservation agrees substantially with that reported by Lovell (1962) and others. In the population tested, 87 months seemed to be the age at which half of the children had acquired the conservation concept. Of equal interest especially to primary teachers is the finding that in a first grade class (at least within our population) three out of ten children might be expected to have this concept; in the second grade, six out of ten might be expected to have the concept, while in the third grade only eight out of ten children can be expected to have the concept. This suggests that to the extent that conservation is an indicator of the child's capability to solve problems by inversion or by compensation, a given primary class will be divided in their instructional needs. Information provided by a means similar to this test should be of considerable diagnostic help to teachers in organizing such a heterogeneous class for instruction.

The order of extinction of precausal forms of explanation found is supportive of the recent description of this development by Piaget (1967) in which he suggests that sequential stages characterized by animism, dynamism and mechanistic explanations characterize children's thinking. The quantitatively smaller amounts of precausal forms of explanation found here are probably due to the picture test methodology. The child's actual precausal explanation may not be present in the limited number of available choices and as a result he would tend to select the one sounding most like the "adult" explanation. This tendency to choose an adult sounding explanation probably masks the extent of precausal explanations actually present.

REFERENCES

Cronbach, L. J. "Coefficient alpha and the internal structure of tests." Psychometrica, 1951, 16, 297-334.

Innis, Robert H. Critical Thinking Readiness in Grades 1-12 (Phase 1: Deductive Reasoning in Adolescence). Cornell Critical Thinking Project. Ithaca, N.Y., 1964. Mimeographed.

Lovell, K. The Growth of Basic Mathematical and Scientific Concepts in Children. University of London Press, 1962.

Piaget, J. The Child's Conception of the World. Littlefield, Adams & Co., 1963.

Piaget, J. "Notions of Causality." SCIS Newsletter, 1967, 9, 4-5.

Scott, W. A. "Measures of test homogeneity." Educational and Psychological Measurement, 1960, 20, 751-757.

Tryon, R. C. & Bailey, D. E. "The BC-TRY Computer System of Cluster and Factor Analysis." Multivariate Behavioral Research, 1966, 1, 95-111.

Watson, G. & Glaser, E. Watson-Glaser Critical Thinking Appraisal. Harcourt, Brace & World, Inc., 1964.

FORM I

THINKING IN SCIENCE

This booklet contains three sets of stories and questions. Each of the three parts is on a different color of paper. The response booklet which has been provided has colored pages which correspond to the colors of the parts of this booklet. Mark your answers on the colored pages of the response sheet. Do not write in this booklet. Listen for additional instructions. Your teacher will tell you when to begin.

ASSUMPTIONS

DIRECTIONS:

An assumption is a belief which is taken for granted. Many assumptions are made without thinking about them. For example, if a boy in the sixth grade says, "I will attend Atwood Junior High School next year," he has made several assumptions. For example, he assumed that he would not move to a different town and he assumed that he would finish the sixth grade satisfactorily.

Many assumptions turn out to be true but a scientist must be able to tell what assumptions have been made. The following problems will let you show whether you can recognize assumptions that are made. The stories written in capitol letters LIKE THIS should be accepted as true. After the stories will be sentences including assumptions. If the sentence is true, draw a circle around the word true on your answer sheet. If the sentence is false draw a circle around the word false on your answer sheet.

Here are two examples, mark your answers.

A SIXTH GRADE BOY SAID, "I WILL ATTEND ATWOOD JUNIOR HIGH SCHOOL NEXT YEAR".

A. The boy must have assumed that Atwood Junior High School will be open next year.

B. The boy must have assumed that there will be more boys than girls attending Atwood Junior High School next year.

You should have marked question A "true", since the boy would expect to attend a school only if he assumed that the school would be open. Question B should be marked "false" since he could have said what he did without assuming there would be more boys than girls attending.

(Do not write in this test booklet)

Questions 1-8 are about the following story.

> A BOY READ THAT A "TIN CAN" IS MOSTLY IRON WITH JUST A THIN LAYER OF TIN COVERING THE IRON. HE WANTED TO FIND OUT IF THIS WAS TRUE. HE WASHED SEVERAL USED CANS TO EXPERIMENT WITH. HE THEN PLACED A MAGNET CLOSE TO ONE CAN. THE MAGNET WAS ATTRACTED TO THE CAN. THE BOY SAID, "ALL OF THESE CANS MUST BE MADE OF IRON".

1. The boy must have assumed that whatever he read was true.

2. The boy must have assumed that magnets are attracted by iron.

3. The boy must have assumed that magnets are attracted by tin.

4. The boy must have assumed that if a magnet was attracted by one can it would be attracted by the others too.

> THE BOY SCRATCHED THE SURFACE OF ONE CAN WITH A NAIL. THE BOTTOM OF THE SCRATCH DID NOT APPEAR DIFFERENT FROM THE SURFACE. HE WRAPPED THE SCRATCHED CAN AND ONE THAT WAS NOT SCRATCHED IN WET NEWSPAPERS. TWO DAYS LATER HE OPENED THE NEWSPAPERS. THE CAN THAT WAS SCRATCHED HAD RED RUST IN THE SCRATCHES. THE OTHER CAN HAD NO RUST. THE BOY SAID, "TIN CANS ARE MOSTLY IRON WITH SOMETHING PROTECTING THE SURFACE".

5. The boy must have assumed that iron would rust when wrapped in wet newspapers.

6. The boy must have assumed that tin would rust when wrapped in wet newspapers.

7. The boy must have assumed that a nail would scratch away tin and expose the iron.

8. When he unwrapped the newspapers the boy must have assumed that two days was long enough for iron to rust.

Questions 9-15 are about the following story.

BETTY FOUND A BOX OF BEAN SEEDS. SHE COULD TELL FROM THE LABEL THAT THE SEEDS HAD BEEN IN THE BOX FOR THREE YEARS. HER BROTHER, NED, WANTED TO THROW THE SEEDS AWAY BUT BETTY DECIDED TO TEST THE SEEDS FIRST. THERE WERE 200 SEEDS IN THE BOX. BETTY PUT 20 SEEDS IN A TRAY BETWEEN LAYERS OF MOIST PAPER.

9. Ned must have assumed that three year old bean seeds will not grow.

10. Betty must have assumed that bean seeds won't grow if they are three years old.

11. Betty must have assumed that she could tell something about all 200 seeds by trying to grow 20.

12. Betty must have assumed that Ned was correct about the seeds.

13. Betty must have assumed that bean seeds need moisture to begin growing.

AFTER THREE DAYS BETTY OPENED THE TRAY. TWELVE OF THE SEEDS HAD STARTED TO GROW. FIVE SEEDS WERE SPLIT OPEN. THE OTHER THREE SEEDS HAD MOLD GROWING ON THEM. BETTY SAID, "If we plant the seeds in our garden, half of them will grow". NED SAID, "They would all grow if they weren't moldy".

14. Betty must have assumed that three days was long enough for the bean seeds to begin to grow.

15. Ned must have assumed that the mold kept some of the seeds from growing.

Questions 16-20 are about the following story.

GRASSHOPPERS

BETTY WANTED TO STUDY THE EATING HABITS OF GRASSHOPPERS. SHE MIXED SUNFLOWER AND GRASS SEEDS TOGETHER AND PLANTED THEM IN POTS. ONE AFTERNOON AFTER THE PLANTS HAD GROWN SHE PLACED ONE POT IN A WIRE CAGE WITH FOUR GRASSHOPPERS CAUGHT THE DAY BEFORE. SHE THEN RECORDED WHICH PLANTS THE GRASSHOPPERS ATE. ALL FOUR GRASSHOPPERS WENT FIRST TO THE SUNFLOWER PLANTS AND BEGAN TO EAT THEM. IN THE PROJECT REPORT, BETTY WROTE 'Grasshoppers choose sunflower plants to eat instead of grass plants'.

16. Betty must have assumed that other grasshoppers would eat the sunflower plants first in the same way as the four she caught.

17. Betty must have assumed that the sunflower plants had more moisture on them than the grass plants.

18. Betty must have assumed that the grasshoppers eat more at night than in the day time.

BETTY ALSO WROTE THE FOLLOWING SUGGESTION IN THE REPORT. 'A row of sunflowers planted around a lawn will provide food and keep the grasshoppers from eating the lawn'.

19. Betty must have assumed that the grasshoppers will eat only sunflower plants as long as they are available.

20. Betty must have assumedthe yellow sunflower plants are easier for the grasshoppers to see.

Questions 21-26 are about the following story.

GROUND SQUIRRELS

A BOY STUDIED GROUND SQUIRRELS BY CATCHING THEM IN CAGES WITH TRAP DOORS. HE WEIGHED THEM, MARKED THEM AND LET THEM GO AGAIN. HE OFTEN CAUGHT THE SAME SQUIRREL SEVERAL TIMES. HE FOUND THAT A SQUIRREL WHICH WAS CAUGHT IN THE MORNING WEIGHED LESS THAN IT DID WHEN CAUGHT AND WEIGHED IN THE AFTERNOON OF THE SAME DAY. BY THE NEXT MORNING, HOWEVER, THE GROUND SQUIRREL WEIGHED ABOUT THE SAME AS IT HAD THE MORNING BEFORE. FOR EXAMPLE, ONE GROUND SQUIRREL WEIGHED 210 GRAMS ONE MORNING, 240 GRAMS WHEN IT WAS CAUGHT IN THE AFTERNOON, AND 211 GRAMS WHEN IT WAS CAUGHT AGAIN THE NEXT MORNING. AFTER HE COLLECTED THE SAME SORT OF INFORMATION FOR FOUR DIFFERENT GROUND SQUIRRELS HE WROTE A LETTER TO HIS FRIEND IN WHICH HE SAID, "Ground squirrels show daily changes in weight. They are light in the morning and heavier in the afternoon."

21. The boy must have assumed that the weight of other ground squirrels changes in the same way as the weight of the four ground squirrels that he caught.

22. The boy must have assumed that catching the ground squirrels had no effect on their weight.

23. The boy must have assumed that the ground squirrels that are caught most frequently show more of a weight change during the day than those that are harder to catch.

IN ANOTHER LETTER THE BOY SAID, "More ground squirrels will be caught by hawks in the afternoon than in the morning since the ground squirrels are heavier and slower then."

24. The boy must have assumed that when a ground squirrel weighs more, it can not run as fast as when it weighs less.

25. The boy must have assumed that the speed of a ground squirrel is an important factor in its ability to escape from hawks.

26. The boy must have assumed that the ground squirrels spend more time underground in their holes in the afternoon than they do in the morning.

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INFERENCES

DIRECTIONS:

When we start with known information, use good reasoning and reach a conclusion, we are using the process called inferring. The conclusion is usually called the inference. For example, Bill who attends Jefferson School noticed that the other children usually played in the school playground until they heard the first bell in the morning. Then they would all stop playing and run toward the building. Suppose one morning Bill stopped on the way to school to watch some men digging with a noisy machine. If Bill did not hear the bell but said, "The bell must have rung", when he saw the children running, he would be making an inference.

Not all inferences turn out to be true. Perhaps the bell was broken and a teacher signaled members of her class to come in by waving. The other children saw several children running toward the school so they all ran toward the school. If this had happened, Bill's inference, "The bell must have rung", would turn out to be false.

Scientists must be able to make inferences which are likely to be true. The following problems will let you decide which inferences are likely to be true, likely to be false or, for which inferences there is not enough information to decide.

The stories written in capitol letters LIKE THIS should be accepted as true. All of the inferences should be based on the information written in capitol letters.

Here are examples; mark answers on your answer sheet.

> BILL LEFT HOME FOR SCHOOL AT 10:00 BY THE CLOCK AT HOME. HIS MOTHER SAID, "HURRY, YOU ARE LATE ALREADY". HE KNEW THAT THE BELL AT SCHOOL RANG WHEN THE SCHOOL CLOCK SHOWED 9:00 AND THAT IT USUALLY TOOK HIM 20 MINUTES TO GET TO SCHOOL. WHEN HE APPROACHED SCHOOL HE SAW MANY CHILDREN ON THE PLAYGROUND. HE REMEMBERED THAT IN THE MORNING THE PLAYGROUND WAS USED ONLY BEFORE SCHOOL AND AT 10:30 RECESS.

Proposed Inferences

A) Bill will be late for school.

B) The clock at Bill's home and the one at school do not agree.

C) The school clock is almost two hours fast.

"Probably true" should be circled for question A since this inference is supported by most of the information in the story. "Can't tell" should be circled for question B because the difference in time is small and might be due to differences in the settings of the clocks or Bill might have taken longer than usual in getting to school. "Probably false" should be circled for question C since it would be unlikely that the school's clock would be so fast and that so many children would arrive at school more than an hour early.

Questions 1-7 are about the following story:

SEEDS

A BOY PLANTED 25 SEEDS FROM THE SAME PACKAGE IN EACH OF FOUR TRAYS. HE USED THE SAME KIND OF SOIL IN EACH TRAY AND PLANTED THE SEEDS IN THE SAME WAY. TRAYS #1 and #2 WERE KEPT IN THE DARK WHILE TRAYS #3 AND #4 HAD 12 HOURS OF LIGHT EACH DAY. TRAYS #1 and #3 WERE KEPT WARM WHILE TRAYS #2 AND #4 WERE KEPT COOL. AFTER 5 DAYS THE PLANTS THAT GREW WERE COUNTED AND MEASURED. HERE ARE THE RESULTS:

	CONDITIONS		SEEDLINGS NUMBER THAT GREW	AVERAGE HEIGHT
TRAY 1	DARK	WARM	19	13 CENTIMETERS
TRAY 2	DARK	COOL	6	16 CENTIMETERS
TRAY 3	LIGHT	WARM	22	7 CENTIMETERS
TRAY 4	LIGHT	COOL	3	4 CENTIMETERS

Proposed Inferences

1. Warm conditions produce more seedlings.
2. Light conditions produce taller seedlings.
3. Warm conditions produce taller seedlings.
4. Dark conditions produce more seedlings.
5. Controlling the temperature is more important than controlling the light-dark condition for obtaining the largest number of seedlings.
6. Controlling the temperature is more important than controlling the light-dark condition for obtaining the tallest seedlings.
7. A dark, warm place is best for raising many tall seedlings from these seeds.

Questions 8-13 are about the following story and graph:

NOISY EGGS

A BIRD EGG MUST BE KEPT WARM FOR A PERIOD OF TIME IF IT IS TO HATCH. THIS TIME IS CALLED THE INCUBATION PERIOD.

TOWARD THE END OF THE INCUBATION PERIOD THE CHICK BECOMES ACTIVE INSIDE THE EGG. A CLICKING SOUND CAN BE HEARD IF AN EGG IS HELD TO YOUR EAR. WHEN ASKED, MOST PEOPLE SAY THAT THE NOISE IS MADE BY THE CHICK TAPPING THE SHELL IN ORDER TO BREAK IT AND GET OUT. OTHER PEOPLE, HOWEVER, HAVE SUGGESTED THAT THE CLICKING NOISE MIGHT BE MADE BY THE TOP AND BOTTOM PART OF THE BIRD'S BILL HITTING WHEN IT CLOSES ITS MOUTH.

IN ORDER TO STUDY HOW THE CLICKING NOISE IS MADE, A SCIENTIST CUT A SMALL HOLE IN A CHICKEN EGG SO THAT HE COULD WATCH THE YOUNG BIRD WHILE LISTENING TO THE CLICKING NOISE.

AS THE SCIENTIST WATCHED THE CHICK HE SAW THE CHICK'S CHEST ENLARGE IN BREATHING AT THE SAME TIME THAT HE HEARD THE CLICKING NOISE. THE BILL DID NOT OPEN AND CLOSE AT THE SAME TIME THAT THE CLICKING WAS HEARD.

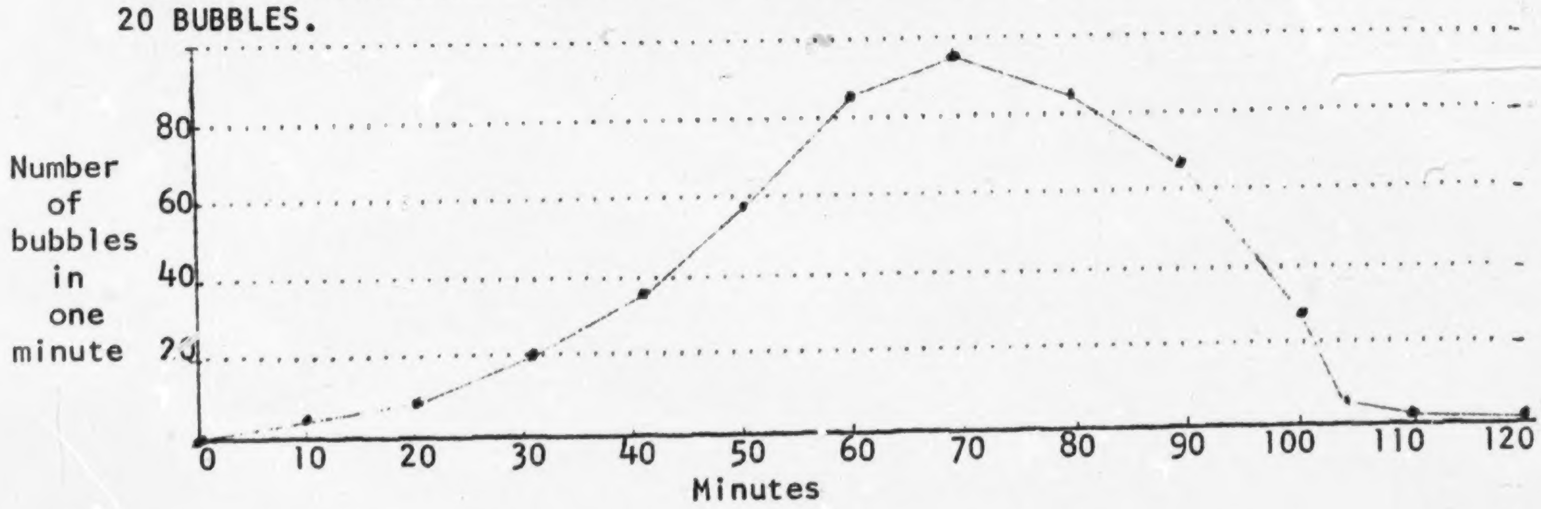
Proposed Inferences

8. The clicking noise is made by the chick trying to get out of the egg.
9. The clicking noise is made by the parts of the chick's bill hitting together as it opens and closes its mouth.
10. The hole in the egg will stop the chick from making noises.
11. The movement of the chick and the clicking sound happened together.
12. The clicking noise is made by the bird's bill hitting the shell as it breathes.
13. The incubation period is shorter for eggs which have observation holes cut in them than for eggs which are left undisturbed.

Questions 14-21 are about the following story and graph:

YEAST

A PACKET OF YEAST CONTAINS TINY, LIVING CELLS WHICH BECOME ACTIVE AND PRODUCE MORE CELLS WHEN PLACED IN WARM WATER WHICH HAS SUGAR DISSOLVED IN IT. A BOY, NAMED JIM, FOUND THAT BUBBLES OF A GAS COME FROM THE YEAST-SUGAR SOLUTION. HE DECIDED TO TRY TO MEASURE THE AMOUNT OF GAS, HE DISSOLVED A PACKET OF YEAST AND A CUP OF SUGAR IN A GALLON JUG OF WATER. HE PUT A STOPPER IN THE TOP OF THE JUG. A SMALL TUBE LET THE GAS BUBBLE OUT OF THE JUG INTO A GLASS OF WATER. JIM THEN COUNTED THE NUMBER OF BUBBLES COMING OUT OF THE JUG IN ONE MINUTE. THE GRAPH SHOWS THE NUMBER HE COUNTED. DURING THE 30TH MINUTE, JIM COUNTED ABOUT 20 BUBBLES.



Proposed Inferences:

14. Jim counted more than eighty bubbles during the sixtieth minute.

15. Jim counted more bubbles during the tenth minute than during the first minute.

16. If Jim had used half as much sugar he would have counted more bubbles.

17. There are more yeast cells in the jug after fifteen minutes than Jim put in to begin with.

18. Jim counted more than twenty bubbles during the tenth minute.

19. If Jim added more sugar after two hours the bubbles would begin again.

20. Bubbles would not have been produced if Jim had used honey instead of sugar.

21. Five times as many bubbles came out during the twentieth minute than during the tenth minute.

Questions 22-26 are about the following story:

SOAP BUBBLES

SOAP BUBBLES PLACED IN A DEEP FREEZER (-20°C) BEHAVE LIKE SOAP BUBBLES AT ROOM TEMPERATURE EXCEPT THAT THEY LAST 5 TO 10 TIMES LONGER BEFORE BREAKING. AT -80°C THE BUBBLES BECOME VERY VISCOUS LIKE COLD HONEY. WHEN THE BUBBLE IS PUNCTURED AT THIS LOW TEMPERATURE, IT SLOWLY COLLAPSES INTO A FLABBY, WRINKLED HEAP. AT -120°C THE BUBBLES BECOME COMPLETELY SOLID.

22. Bubbles that last for 15 seconds at room temperature would last for more than a minute in a deep freezer.

23. Soap bubbles filled with pure oxygen would last longer than those filled with air.

24. Soap bubbles made outside on a warm summer day will last longer than those made outside on a cold winter day.

25. If the bubbles were made from a different kind of soap they would behave in the same way.
26. The solid bubbles at the lowest temperature are breakable like thin glass.

REASONING

The problems in this part are to see how well you can do a particular kind of thinking called reasoning. In these problems there will be two sentences written in capitol letters LIKE THIS. For the purpose of doing the problem you should accept these sentences as true even though you might not agree. After the two sentences in capitol letters there will be another sentence written with only normal use of capitols but underlined like this. You must decide about the truth of the third sentence by reasoning with the information in the first two.

You must choose one of three answers. Draw a line around "it must be true" if you determine from the first two sentences that the third sentence must be true on the answer sheet. Draw a line around "it can't be true" if you determine from the first two sentences that the third sentence cannot be true. Draw a line around "can't tell" if you weren't told enough from the first two sentences to be sure that the third sentence is true or not true.

Here is a sample problem. Draw a line around the correct answer on the answer sheet.

A. Suppose it is true that
ALL LIONS ARE BLACK
LEO IS A LION
Then is it true that
Leo is black
?

You should have drawn a line around "it must be true". Even though all lions are not black, you must suppose that they are in order to do the problem.

Do the following problems using your best reasoning ability.

1. Suppose it is true that
THE YELLOW CRAYON IS LONGER THAN THE BLUE CRAYON.
THE YELLOW CRAYON IS LONGER THAN THE RED CRAYON.
Then is it true that
The red crayon is longer than the blue crayon
?

2. Suppose it is true that
SUE IS TALLER THAN FRANK.
FRANK IS TALLER THAN JIM.
Then is it true that
Sue is taller than Jim
?

3. Suppose it is true that
ALL CATS LIKE TO DRINK MILK.
MY PET LIKES TO DRINK MILK.
Then is it true that
My pet is a cat
?

4. Suppose it is true that
EVERY SUNDAY IS A RAINY DAY.
TODAY IS A RAINY DAY.
Then is it true that
Today is Sunday
?

5. Suppose it is true that
ALL YELLOW PENCILS HAVE ERASERS.
BILL'S PENCIL HAS AN ERASER.
Then is it true that
Bill's pencil is yellow
?

6. Suppose it is true that
THE RED PENCIL IS LONGER THAN THE BLUE PENCIL.
THE BLUE PENCIL IS LONGER THAN THE YELLOW PENCIL.
Then is it true that
The red pencil is longer than the yellow pencil
?

7. Suppose it is true that
ALL OF THE YELLOW PENCILS ARE BROKEN.
JIM'S PENCIL IS NOT BROKEN.
Then is it true that
Jim's pencil is yellow
?

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8. Suppose it is true that
NED IS TALLER THAN BILL.
BILL IS TALLER THAN JIM.
Then is it true that
Jim is taller than Ned.
?

9. Suppose it is true that
EVERY SUNDAY IS CLOUDY.
TODAY IS SUNDAY.
Then is it true that
Today is cloudy
?

10. Suppose it is true that
ALL SPARROWS ARE SMALL BIRDS.
ALL SMALL BIRDS ARE YELLOW.
Then is it true that
All sparrows are yellow
?

11. Suppose it is true that
BILL HAS MORE MILK THAN JIM.
JIM HAS MORE MILK THAN MIKE.
Then is it true that
Mike has more milk than Bill
?

12. Suppose it is true that
ALL DOGS HAVE SHARP TEETH.
JERRY'S PET IS NOT A DOG.
Then is it true that
Jerry's pet has sharp teeth
?

13. Suppose it is true that
SUE HAS MORE MILK THAN JOAN.
JOAN HAS MORE MILK THAN MIKE.
Then is it true that
Mike has more milk than Sue
?

14. Suppose it is true that
ALL OF THE YELLOW PENCILS HAVE ERASERS.
ANN'S PENCIL DOES NOT HAVE AN ERASER.
Then is it true that
Ann's pencil is yellow
?

15. Suppose it is true that

ALL OF THE RED PENCILS ARE BROKEN.
JANE'S PENCIL IS BROKEN.

Then is it true that

Jane's pencil is red
?

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16. Suppose it is true that

ALL OF THE ARITHMETIC BOOKS HAVE BLUE COVERS.
MIKE'S FAVORITE BOOK DOES NOT HAVE A BLUE COVER.

Then is it true that

Mike's favorite book is his arithmetic book
?

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17. Suppose it is true that

THE BLACK PENCIL IS LONGER THAN THE BLUE PENCIL.
THE GREEN PENCIL IS LONGER THAN THE WHITE PENCIL.

Then is it true that

The white pencil is longer than the black pencil
?

---

18. Suppose it is true that

ALL MICE ARE SMALL ANIMALS.
ALL SMALL ANIMALS ARE BLACK.

Then is it true that

All mice are black
?

---

19. Suppose it is true that

ALL CHILDREN WHO LIVE ON A FARM HAVE PETS.
BILLY HAS A PET.

Then is it true that

Billy lives on a farm
?

---

20. Suppose it is true that

JANE IS A GIRL WHO GOES TO OUR SCHOOL.
ALL OF THE GIRLS WHO GO TO OUR SCHOOL ARE HAPPY.

Then is it true that

Jane is happy
?

---

21. Suppose it is true that

BILL HAS MORE SODA POP THAN JIM.
BILL HAS MORE SODA POP THAN FRANK.

Then is it true that

Jim has more soda pop than Frank
?

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---

22. Suppose it is true that
JIM IS IN THE FOURTH GRADE.
THERE ARE NO TALL BOYS IN THE FOURTH GRADE.
Then is it true that
Jim is tall
?

23. Suppose it is true that
ALL FAST SWIMMERS ARE BOYS.
NO FAST RUNNERS ARE BOYS.
Then is it true that
Some fast swimmers are fast runners
?

24. Suppose it is true that
ALL CATS HAVE LONG TAILS.
SALLY'S PET IS NOT A CAT.
Then is it true that
Sally's pet has a long tail
?

25. Suppose it is true that
JOAN HAS MORE SODA POP THAN SUE.
SUE HAS MORE SODA POP THAN BILL.
Then is it true that
Joan has more soda pop than Bill
?

26. Suppose it is true that
ALL DOGS LIKE TO EAT MEAT.
MY PET LIKES TO EAT MEAT.
Then is it true that
My pet is a dog
?

BTCT

Form I

RESPONSE BOOKLET

1. ____________
2. ____________
3. ____________
4. ____________
5. ____________
6. ____________
7. ____________
8. ____________
9. ____________
10. ____________
11. ____________
12. ____________
13. ____________
14. ____________
15. ____________
16. ____________
17. ____________
18. ____________
19. ____________
20. ____________

_____ Boy

Name ______________________________ _____ Girl

Birthdate ________ ________ ________
day month year

School ______________________________

Teacher ______________________________

Thinking About Causes

This activity will give you an opportunity to show how well you can think of different causes of things that happen. Suppose this happened:

> You and a friend are hiking in a field and find a place where all of the plants are bent over or are lying on the ground. You wonder what could cause the plants to be bent over this way.

What could cause this to happen? List all of the causes you can think of in the spaces on this page. Use your imagination to think of unusual and different causes. If you need more space, use the back of this page.

1. ______________________________.
2. ______________________________.
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10. ______________________________.
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14. ______________________________.
15. ______________________________.
16. ______________________________.
17. ______________________________.
18. ______________________________.
19. ______________________________.
20. ______________________________.

Asking Questions

This activity will give you an opportunity to show how well you can think of questions to ask. Suppose this happened:

A playmate discovered a hole in the ground by the school and ran over to tell you and your friends about it.

What questions would you ask to find out more about what happened. Think of as many different questions as you can. Write as many questions as you can think of in the spaces on this page. If you need more space, use the back of this page.

1. ____________________.
2. ____________________.
3. ____________________.
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15. ____________________.
16. ____________________.
17. ____________________.
18. ____________________.
19. ____________________.
20. ____________________.

Unusual Uses

This activity will give you a chance to think of unusual ways to use something commonly found in a science class. How many unusual uses can you think of for a flashlight battery?

List as many different uses as you can think of in the spaces on this page. You may list uses that you have seen or heard about but also include uses of a flashlight battery that are new and different. Use the back of this page if you need more space.

1. ______________________________.
2. ______________________________.
3. ______________________________.
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16. ______________________________.
17. ______________________________.
18. ______________________________.
19. ______________________________.
20. ______________________________.

Improving A Tool

This activity will give you an opportunity to think of ways to improve something so that it will be better or more useful.

> A boy needed something to lift pieces of metal out of hot water. He made a tool out of two strips of metal by connecting them together with a bolt. The tool works something like a pair of scissors.

Think of as many different ways of improving this tool as you can. The changes should make the tool easier to use or made it more useful tool for handling things that are too hot, too cold or dangerous to touch. List all of the ways to improve this tool on the spaces on this page. Use the back of this page if you need more space.

1. ____.
2. ____.
3. ____.
4. ____.
5. ____.
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8. ____.
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12. ____.
13. ____.
14. ____.
15. ____.
16. ____.
17. ____.
18. ____.

ASSUMPTIONS - ANSWER SHEET

Examples:	A-	True	False	-A
	B-	True	False	-B
	1-	True	False	-1
	2-	True	False	-2
	3-	True	False	-3
	4-	True	False	-4
	5-	True	False	-5
	6-	True	False	-6
	7-	True	False	-7
	8-	True	False	-8
	9-	True	False	-9
	10-	True	False	-10
	11-	True	False	-11
	12-	True	False	-12
	13-	True	False	-13
	14-	True	False	-14
	15-	True	False	-15
	16-	True	False	-16
	17-	True	False	-17
	18-	True	False	-18
	19-	True	False	-19
	20-	True	False	-20
	21-	True	False	-21
	22-	True	False	-22
	23-	True	False	-23
	24-	True	False	-24
	25-	True	False	-25
	26-	True	False	-26

INFERENCE - ANSWER SHEET

A-	Probably True.	Can't Tell.	Probably False.	-A
B-	Probably True.	Can't Tell.	Probably False.	-B
C-	Probably True.	Can't Tell.	Probably False.	-C
1-	Probably True.	Can't Tell.	Probably False.	-1
2-	Probably True.	Can't Tell.	Probably False.	-2
3-	Probably True.	Can't Tell.	Probably False.	-3
4-	Probably True.	Can't Tell.	Probably False.	-4
5-	Probably True.	Can't Tell.	Probably False.	-5
6-	Probably True.	Can't Tell.	Probably False.	-6
7-	Probably True.	Can't Tell.	Probably False.	-7
8-	Probably True.	Can't Tell.	Probably False.	-8
9-	Probably True.	Can't Tell.	Probably False,	-9
10-	Probably True.	Can't Tell.	Probably False.	-10
11-	Probably True.	Can't Tell.	Probably False.	-11
12-	Probably True.	Can't Tell.	Probably False.	-12
13-	Probably True.	Can't Tell.	Probably False.	-13
14-	Probably True.	Can't Tell.	Probably False.	-14
15-	Probably True.	Can't Tell.	Probably False.	-15
16-	Probably True.	Can't Tell.	Probably False.	-16
17-	Probably True.	Can't Tell.	Probably False.	-17
18-	Probably True.	Can't Tell.	Probably False.	-18
19-	Probably True.	Can't Tell.	Probably False.	-19
20-	Probably True.	Can't Tell.	Probably False.	-20
21-	Probably True.	Can't Tell.	Probably False.	-21
22-	Probably True.	Can't Tell.	Probably False.	-22
23-	Probably True.	Can't Tell.	Probably False.	-23
24-	Probably True.	Can't Tell.	Probably False.	-24
25-	Probably True.	Can't Tell.	Probably False.	-25
26-	Probably True.	Can't Tell.	Probably False.	-26

"Probably true" means probably a true statement but there is a small chance that the statement is false.

"Can't tell" means there is not enough information in the story to decide whether the sentence is true or false.

"Probably false" means probably a false statement but there is a small chance that the statement might be true.

REASONING - ANSWER SHEET

Sample Problem:

A-	It must be true.	Can't tell.	It can't be true.	-A

1-	It must be true.	Can't tell.	It can't be true.	-1
2-	It must be true.	Can't tell.	It can't be true.	-2
3-	It must be true.	Can't tell.	It can't be true.	-3
4-	It must be true.	Can't tell.	It can't be true.	-4
5-	It must be true.	Can't tell.	It can't be true.	-5
6-	It must be true.	Can't tell.	It can't be true.	-6
7-	It must be true.	Can't tell.	It can't be true.	-7
8-	It must be true.	Can't tell.	It can't be true.	-8
9-	It must be true.	Can't tell.	It can't be true.	-9
10-	It must be true.	Can't tell.	It can't be true.	-10
11-	It must be true.	Can't tell.	It can't be true.	-11
12-	It must be true.	Can't tell.	It can't be true.	-12
13-	It must be true.	Can't tell.	It can't be true.	-13
14-	It must be true.	Can't tell.	It can't be true.	-14
15-	It must be true.	Can't tell.	It can't be true.	-15
16-	It must be true.	Can't tell.	It can't be true.	-16
17-	It must be true.	Can't tell.	It can't be true.	-17
18-	It must be true.	Can't tell.	It can't be true.	-18
19-	It must be true.	Can't tell.	It can't be true.	-19
20-	It must be true.	Can't tell.	It can't be true.	-20
21-	It must be true.	Can't tell.	It can't be true.	-21
22-	It must be true.	Can't tell.	It can't be true.	-22
23-	It must be true.	Can't tell.	It can't be true.	-23
24-	It must be true.	Can't tell.	It can't be true.	-24
25-	It must be true.	Can't tell.	It can't be true.	-25
26-	It must be true.	Can't tell.	It can't be true.	-26